The Computer Music Designer (CMD) In The Context Of Physical Computing And Interactive Instrument Design

Brunel University London

A thesis submitted for the degree of Doctor of Philosophy in the College of Business, Arts and Social Sciences, Brunel University London

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Acknowledgements

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Declarations

Declaration of Authorship

I, Ardeshir Mostajeran Gourtani, declare that this thesis titled, *The Computer Music Designer (CMD) In The Context Of Physical Computing And Interactive Instrument Design* and the work presented in it is my own.

I declare that:

(I) This thesis has been solely the result of my own work composed by the candidate, and either that the work is the candidate's own, or, if the candidate has been a member of a research group, that the candidate has made a substantial contribution to the work, such contribution is clearly indicated.

(II) I declare that this thesis is an original report of my research, has been written by me and has not been submitted for any previous degree or professional qualification except as specified. The experimental work is almost entirely my own work; the collaborative contributions have been indicated clearly and acknowledged. Due references have been provided on all supporting literature and resources.

(III) The data presented in this thesis was obtained in an experiment carried out by different collaboration in several locations of experiment/where collaborations happened. I played a major role in the preparation and execution of the experiment, and the data analysis and interpretation are entirely my own work. Any contributions from colleagues in the collaboration, such as diagrams or calibrations, are explicitly referenced in the text.

(IV) The work submitted is my own, except where work that has formed part of jointly authored publications has been included. My contribution and those of the other authors to this work have been explicitly indicated below. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

(V) I am aware of and understand the university's policy on plagiarism and I certify that this thesis is my own work, except where indicated by the reference, and the work presented in it has not been submitted in support of another degree or qualification from this or any other university or institute of learning.

Signed: Ardeshir M.Gourtani

Date: 18 December 2018

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Abstract

This thesis explores the role of the Computer Music Designer in the development of interactive instruments within the context of collaborative work with other creative artists. The recent development of physical computing and the devices and techniques associated with human/computer interactivity has had a strong influence on the place the CMD occupies in a creative project. My thesis presents a selection of unique projects undertaken during the course of my research in order to further establish the role the CMD plays in collaborative creations, in particular how this figure can shape innovation through Max programming, data manipulation, interface design.

Recent studies have established the CMD's highly specialised role in collaborative work and their capacity to harness musical experiences as a performer and composer with special technology and technical skills. This submission extends research in this area by focusing on the role of the CMD as a creator of interactive sensor-based digital instruments influenced by advances in physical computing technologies. I present the hidden creative process of collaborative projects as well as emerging technology and digital tools through the production process of selected bespoke projects.

As well as taking into consideration the important place of collaboration in the development of computer music creation, the thesis also scrutinises the collaborative process between the CMD and other creative artists working in more established roles, arguing that a wider appreciation of the new forms of musical expression offered by emerging technology continues to present challenges in collaborative work and that these necessitate the specialist skills of the CMD.

Chapter I: Introduction and context

The focus of this thesis begins in the late 1950s when computer music was first widely developed by researchers and composers such as Iannis Xenakis, Lejaren Hiller, Joel Chadabe, Miller Smith Puckette, Karlheinz Stockhausen, Gottfried Michael Koeing, Trevor Pearcey, and David Zicarelli. The work of Max Vernon Mathews and the collaboration between Miller Smith Puckette and Philippe Manoury is of special importance in the context of computer music and the role of CMD. While other figures have done similar work in the field, these are the most salient to this thesis.

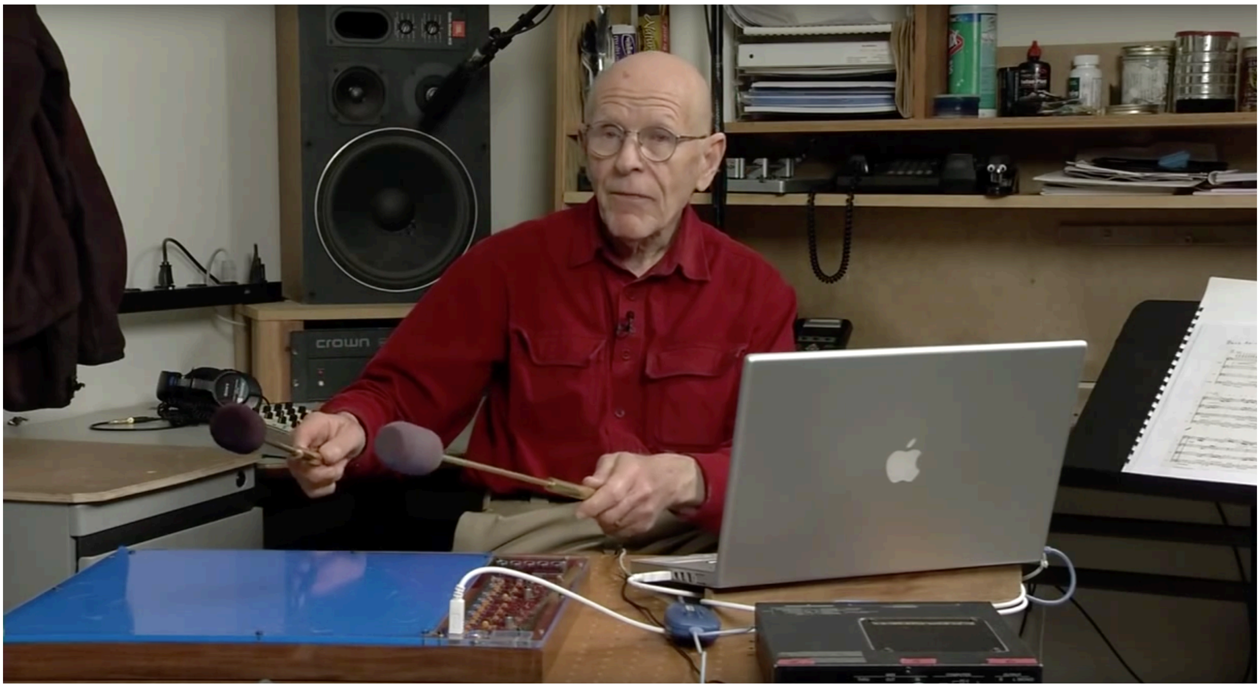

Figure 1. Max Vernon Mathews and the Radio Baton.

Max Vernon Mathews, acknowledged as the pioneer of computer music while working at Bell Labs, successfully demonstrated the computer generation of sound for the first time using a digital-to-analogue converter (Holmes, p. 216). In 1965 Mathews, alongside William Ninke and L. Losler at Bell Labs, developed the ‘Graphic 1’ system, a graphical interface for composing music. The output of the process was stored and could be played back using computer synthesis. This was the first successful computerfriendly experiment using software to draw, copy, erase, and edit musical values on a computer (Nunzio, 2018).

Figure 2. 'Graphic 1' William H. Ninke, Carl Christensen, Henry S. McDonald and Max Mathews. USA, 1965. (Nunzio, 2018).

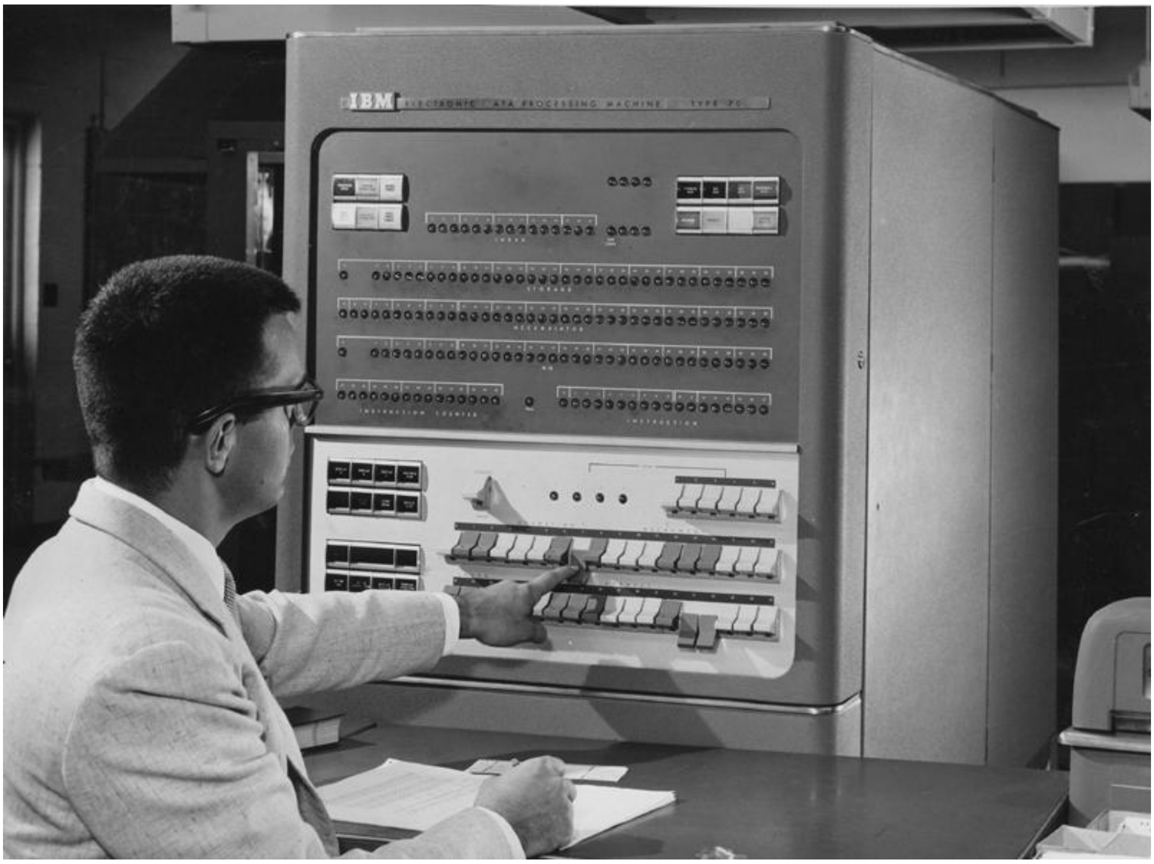

Figure 3. The IBM704b at Bell Labs used with the Graphics 1 system.

For the rest of the century, Mathews remained a leader in digital audio research, synthesis, and human-computer interaction in music performance. At Bell Labs, he created the Radio Baton in 1976 as part of his Conductor Program. This program consisted of three stages:

1. Note input to the computer’s memory.

2. The rehearsal stage, including phrasing, accents and other articulation.

3. The performance stage where all the voices are played back together.

The Conductor Program allowed for devices to conduct/control different dimensions of music during the second stage. While Mathews ran into some problems with his devices his later collaboration with Robert Boie, in 1987, at Bell Labs solved these problems and led to the development of the highly successful Radio Baton, an example of trial, error and eventual collaboration, which is one of the primary activities of the CMD.

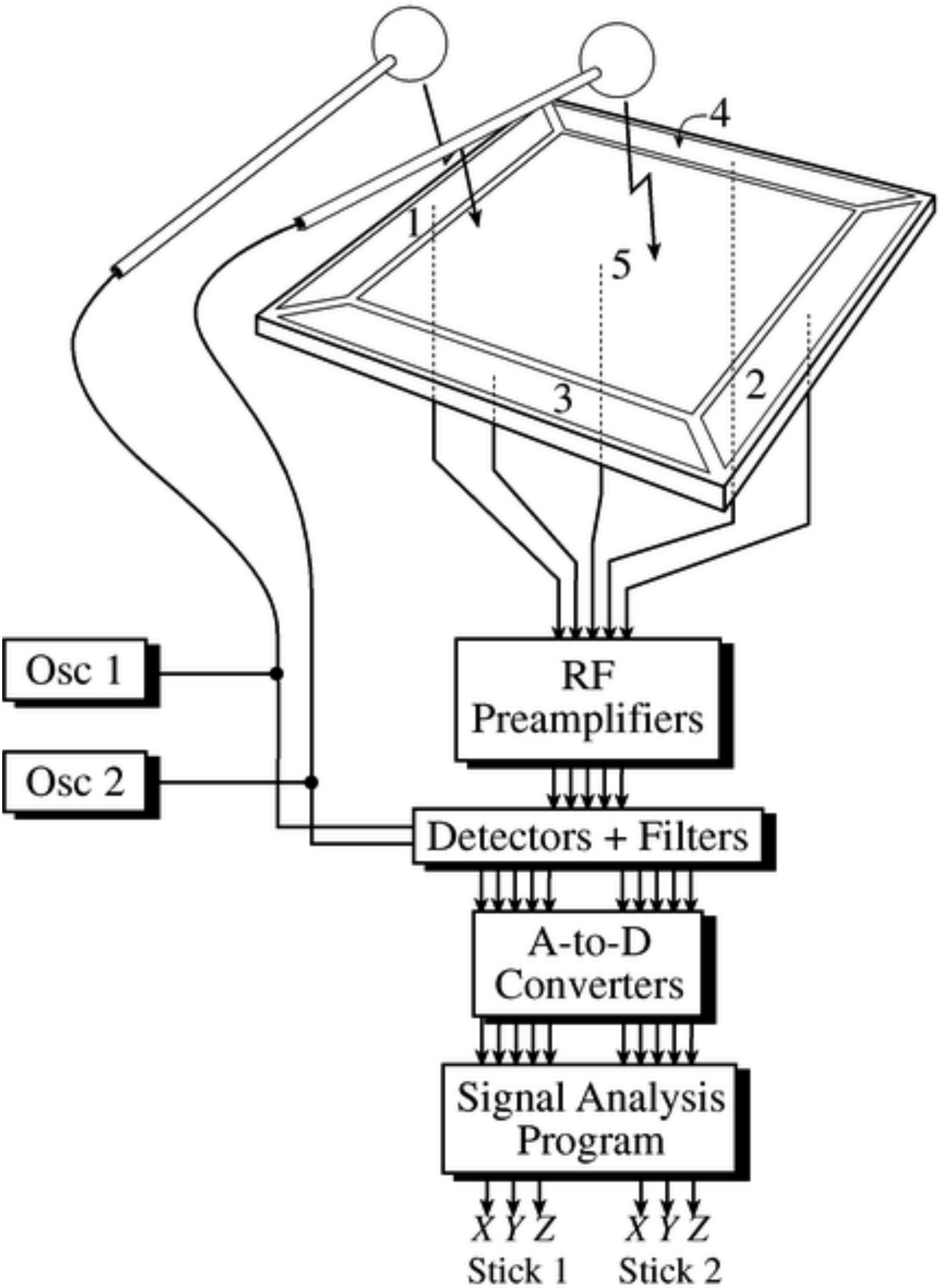

Figure 4. Radio Baton diagram.("6.3 Radio Baton", 2018).

In 1988, Miller Puckette created Max, the first graphical compiler program (Puckette 2007, p. xi). Since the 1980s, the French composer Philippe Manoury has been closely collaborating with Miller Puckette at IRCAM and UCSD, on the *Sonus Ex Machina* series of works, which included the first pieces to utilise real-time audio signal processing: *Jupiter* (1987) for flute solo and 4x and in 1988, *Pluton* for piano solo and computer electronics, the first composition using Puckette's Max software.

Figure 5. New Music in San Diego: Left to right Miller Puckette, Juliana Snapper, Philippe Manoury. (Matthews, 2018).

This program, running on the NeXT computer, dealt only with control signals for music synthesis on the 4X digital signal processing computer as computers were not yet fast enough to process sound. As computers became faster, Puckette and David Zicarelli changed Max to Max MSP, a real-time compiler capable of live music performance (Puckette 2007, p. xi).

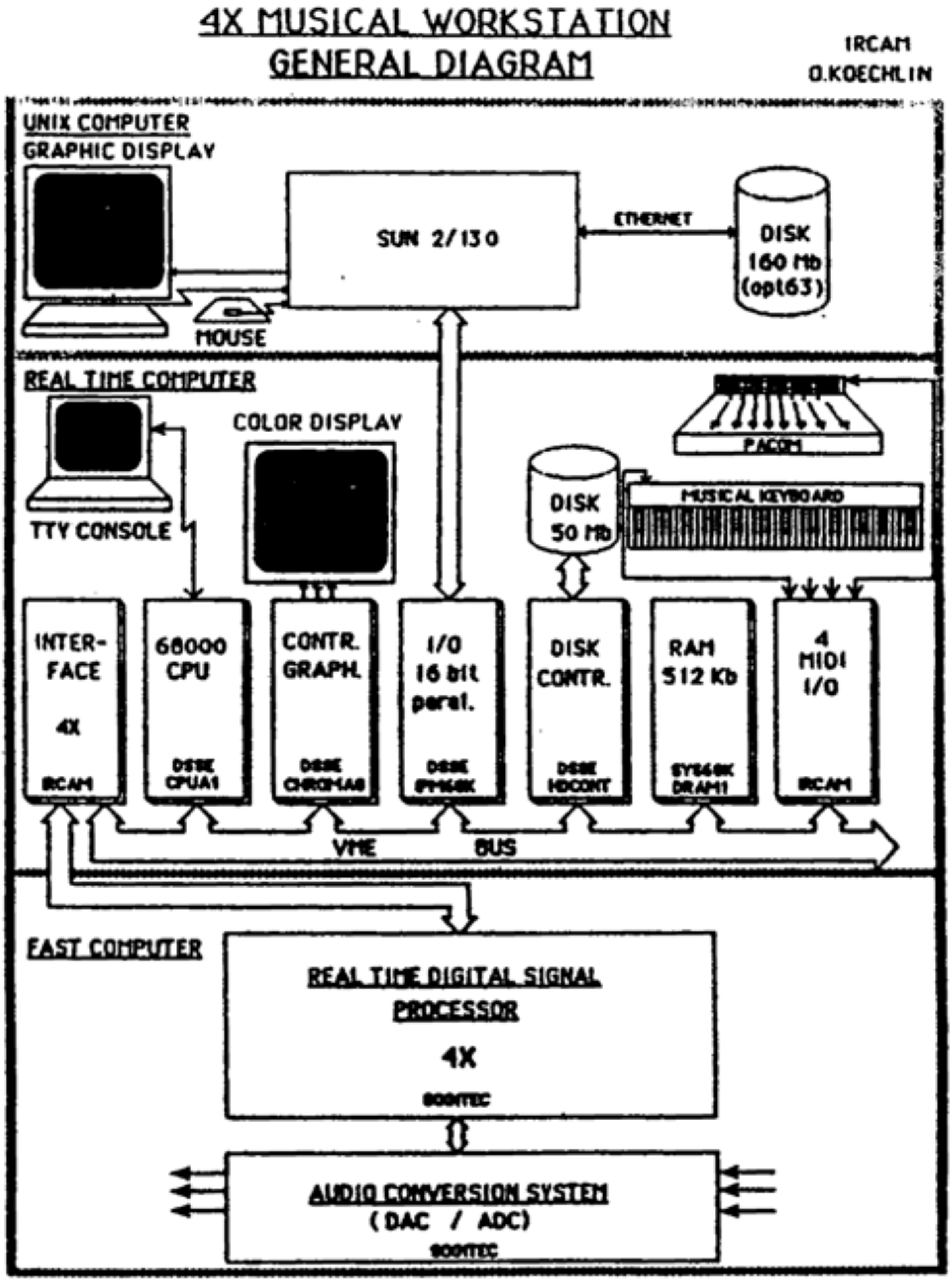

Figure 6. 4X Musical workstation general diagram.

Figure 7. Giuseppe Di Giugno with the 4X at IRCAM.("Sogitec 4X synthesiser. Giuseppe Di Giugno, France, 1981", 2018).

More recently, researchers and composers have considered the importance of the newly emerging role of the CMD and have attempted to describe this unique role in collaborative creation, a role that challenges established relational structures usually involved in music collaboration. The role was previously regarded as primarily — a musical assistant, a technician, a tutor, or a mediator (Faia/Zattra/Gerzso)— has evolved into that of creative partner with knowledge of new music creation technology, proficient musical knowledge and experience as a performer, composer, programmer and sound designer. (Faia p.18)

In *Electronic Sound: The Past and Promise of Electronic Music,* Joel Chadabe writes:

> The technologies of musical instruments – whether the wood and glue of a violin case, the mechanical hammers and levers of a piano action, or the electronic microprocessors used in synthesisers – have reflected the times and places of their inventions. The violin, for example, made with hand tools and containing no moving part, is a product of seventieth-century European pre-industrial-age technology. The piano, a wooden machine with many moving parts, is a product of nineteenth-century European industrial age technology. (Chadabe,1997 p. viii).

Chadabe is pointing out that people throughout time have made music with what was available and today when technology is a central aspect of life, people are integrating technology into making music. He goes on to say:

> The electronic musical instrument, in its myriad forms, has particular promise. It may well turn out to be the most beneficial to humans and the most enjoyable, rewarding and expressive instrument that has ever existed.

I.a Research questions

1. What are the CMD’s role and limitations when collaborating?
2. Does collaborative creation facilitate innovation in the design of interactive instruments and new work?
3. What are the limits and restrictions of collaborative work in terms of innovation in music technology and sound design?
4. What is the importance of Max and similar programs in the collaborative process?
5. How might the CMD enhance performance/composition through the development of interactive instruments?

This thesis explores how technology has influenced collaboration and in turn how collaborative work can shape the development of interactive instrument creation. It does this through consideration of several collaborative projects undertaken during my research. It also considers the tension between the new possibilities brought about by the CMD through the use of evolving technology. Three projects were chosen which offered the opportunity to work alongside a range of musicians and other artists in the development and utilisation of sensor technologies and Max programming. Additional collaborations and projects are collected in the Appendix.

It is important to understand one’s partner in any collaboration, their age, experience, mindset, ambitions, etc. when performers or composers are not clear about what they want or need, or do not know what is possible, my role as the CMD was to provide possible solutions. While this differs from project to project (many rejected suggestions or fewer more targeted suggestions) the role of the CMD becomes something of a tutor or teacher before taking on the technology of the project. As a

CMD, I have had to familiarise myself with the technologies that performers have used for a long time (e.g. foot pedals as triggers), even if I feel there are better alternatives.

These questions also answered in more details in the next three chapters and the conclusion of this thesis.

I.b The collaborative role of the CMD

Dr Carl Faia's work has stressed the importance of validating the role of the CMD as a new entity within the world of music creation (Faia, *Collaborative Computer Music Composition and the Emergence of the CMD,* p. 8). In addition, Dr Laura Zattra has drawn attention to the increasing awareness of the role of the CMD and the importance of developing literature dedicated to this field (Zattra, *Collaborative Creation in Electroacoustic Music,* p. 10). This submission hopes to contribute to this growing body of work by focusing specifically on the role of the CMD as an interactive instrument designer.

As Faia and Zattra have observed, the depth and breadth of the CMD's expertise in both traditional music composition and performance, as well as in new technologies, often goes unrecognised and their contributions to collaboration tend to be underestimated. Faia concludes that music is ultimately a collaborative art form. Technology has played an important role in the collaboration between the performer and the CMD.

> There is the prevalent consensus in serious music circles that the composer should be the master of everything: not just the composition of the work, but also the orchestration and even the performance of the work as conductor or instrumentalist. (Faia, p. 15).

Andrew Gerzso observed three different kinds of artistic research in his article,[1]' Aspects of Musical Research at IRCAM': individual or private research, collective research among artists, and collective research between artists and scientists. Gerzso observed that the vast majority of artistic research takes place in individual or private research (Gerzso, p. 5). The second type of research, collective research among artists, is characterised by artists who are motivated by common concerns, such as the collaboration between composer John Cage and choreographer Merce Cunningham (Gerzso, p. 6). Lastly, collective research is characterised by artists and scientists (or developers of technology) working together, motivated by differing professional objectives but with an identifying common ground (Gerzso, p. 6). The CMD, often with experience in both worlds as creator and researcher, plays the role of liaison between scientist and artist to create and realise the new forms of technology-based creations including interactive instruments, live electronics, and customised programs created for specific creative needs.

Over the years the need for collaboration among composers on computer music requirements has increased and workshops, seminars, and collaborative projects have expanded to meet these needs. For example, Laurent Pottier, professor and CMD from Ircam, has created a Masters programme at the University of Lyon leading to a Diploma in Collaborative Computer Music Design [2](Réalisateur en Informatique musicale).

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[1] Andrew Gerzso (2013) Aspects of Musical Research at IRCAM, Contemporary Music Review, 32:1, 5-15, DOI: 10.1080/07494467.2013.774123.

[2] V3, A. (n.d.). Université Jean Monnet - UJM. Retrieved October 13, 2017, from https://www.univ-st-etienne.fr/fr/index.html.

I.c Defining an instrument

As well as redefining traditional roles and processes in music collaboration, advances in technology also challenge established definitions of an instrument. As Bert Bongers notes:

> Musical instruments are extreme examples of precise, expressive and versatile interfaces. With the transition to the use of electronics as a sound source, a new type of non-mechanical instrument was needed. The limitations of mechanical systems (e.g. the length, thickness and tension of a string is directly related to its pitch and timbre) have also gone, which means that there is almost total freedom in the design of the instrument. (Bert Bongers, *Electronic Musical Instruments: Experiences of a New Luthier,* 2017, p. 9).

Technology has also played a pivotal role in defining an instrument. Andrew Gerzso observes that real-time technologies have introduced a new aspect of interpretation and musical performance through technology (Gerzso, p. 7). Sound analysis and synthesis technology have expanded the concepts of instrument building. The new developments have impacted the sound engine in instrumental performances.

As Atau Tanaka notes in his discussion of sensor-based instruments, the traditional understanding of a musical instrument such as the member of a classical orchestra as ‘a self-contained and autonomous sound-producing object that enables a musician to perform in a live situation’ is no longer adequate to describe the kind of instruments currently being developed due to recent advances in technology. A more suitable definition for this new kind of instrument which incorporates varied software and hardware is an ‘open-ended system comprised of multiple components. A musical instrument system can include input devices, mapping algorithms, sound synthesis engine, compositional structure, and output system. An input device is often a sensor and data subsystem to capture performer gestures. Mapping algorithms is a software subsystem to interpret gestural data into musical information. Sound synthesis engine is a real-time audio generation in which sound synthesis parameters are modulated by live input ' (Roger T Dean, The Oxford Handbook of Computer Music. Oxford, 2011, "Tanaka" p. 238). Compositional structure is a layer defining the musical selections. Lastly, the output system consists of an output channel configuration and digital to analogue converters (DAC).

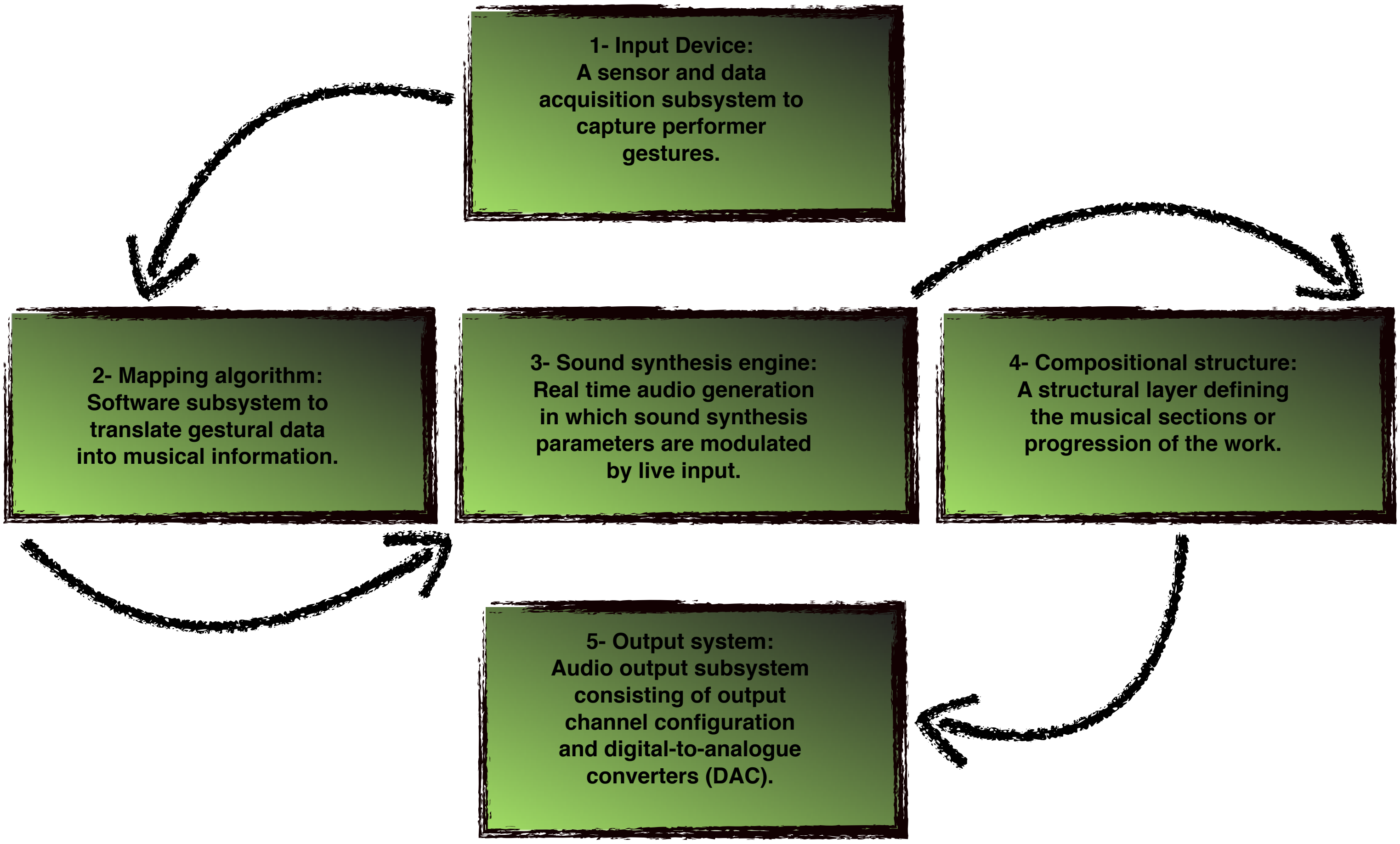

Figure 8. Musical instrument system diagram.

Tanaka argues that the redefinition of a musical instrument raises several questions:

> Is the instrument just the sensor hardware, or does it include software components like the mapping and sound synthesis software subsystems? Where do the instrument end and the composition begin? Is the entire system specific for one musical work, or can parts of it (e.g., the synthesis or compositional components) be altered or generalised to create different works for the same instrument? What happens to the boundaries distinguishing traditional roles of instrument builder, composer, and performance.

I.d Defining my methods

One of the techniques I use might corresponds to a surrealist technique developed by Salvador Dali, the “paranoiac-critical method”. The aspect of paranoia that interested Dali was the brain’s ability to perceive links between things that are not linked rationally. Dali described the paranoiac-critical method as a ‘spontaneous method of irrational knowledge based on the critical and systematic objectivity of the associations and interpretations of delirious phenomena.’(‘The Dali Foundation acquires a surrealist painting’, Salvador-Dali.org, 2018).

The paranoiac-critical method is similar to the thought process of an artist when they are creating a piece of work. They might use their imagination before starting their project to see what unrelated objects can be combined to create a new outcome. This is similar to the process of making a program or an application in Max or other existent programs. In making a program, a programmer starts with a blank slate just as an artist begins with a blank canvas. The important fact is how ideas are brought together from a blank slate and then the outcome is a fine piece of painting or application.

When the Max patch has been made, I might consider it as if it were a painting in the sense to which Miller Puckette alludes when he says of the Max programming environment that: ‘The resulting graphical display is very congenial to musicians’ and that is possible to ‘understand how complex instruments work by looking at their graphical images’. (Puckette 2007, p. xi).

Another technique I use is based on the ‘Lotfi Zadeh fuzzy logic approach’. Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1(“What is 'fuzzy logic'? Are there computers that are inherently fuzzy and do not apply the usual binary logic?” N.D,). The concept of partial truth, where the truth value may range between completely true and completely false, is handled by fuzzy logic. This is similar to when I am programming. To analyse data, I create mathematical formulae to achieve different tasks. Even though the techniques of the paranoiac-critical method and fuzzy logic method do not directly relate to music, the process is very similar to the techniques and processes I use in developing different applications and programs, such as those collaborations with drama and music students as well as the Chelsea Flower Show project.

In broader terms, while creative programming and mapping incoming data, the programmer or CMD has to consider, among many other parameters, mathematical manipulations of massive streams of information. Consider what happens if we are receiving data from a sensor into a program through a device in which the numbers are floating number between 0. and 1.0. If the numbers are, for example, 0.1 and 0.5, what are the possible variables for these data sets? Are we going to use them to rotate a mechanical step motor or simply use them to change different parameters in relation to sound effects or video? It does not matter what process needs to be done; but it is very important to know how to interpret and map the incoming data to achieve a goal.

In describing the vast possibilities available with this technology and the need to decide and interpret the data made available with these new technologies, Laetitia Sonami writes:

> My signature instrument, the “lady’s glove”, is fitted with a vast array of sensors that track the slightest motion of my enigmatic dance: with it, I can create performances where my movements can shape the music and in some instances visual environments. The lady’s glove has become a fine instrument that challenges notions of technology and virtuosity. (Sonami.net, 2018).

There is an emphasis on knowing what process can solve different problems occurring during the programming, performance or event, and there is rarely enough time to react logically to these problems: consequently, it is often the role of the CMD to solve all these issues immediately. Working in this environment can depend on a changing number of variables and there is not always the same answer to unforeseen questions. As a result, the CMD is required to work with random mathematics and convert it to a logical solution for different projects, or vice versa, regularly.

Finally, the element of chance in any artistic work has many possible expressions. There is an element of chance in the way I am working with the computer and in my collaborations. I believe that chance opens gates that nobody has opened before. As Joel Chadabe says of John Cage, ‘Chance made possible the discovery of new combinations of things, new events that would not have occurred had he relied on what he already knew, had already experienced, and already found pleasing.’ In 1961, Cage wrote:

> What happened was that when things happened that were not in line with my views as to what would be pleasing, I discovered that they altered my awareness. That is to say, I saw that things which I did not think would be pleasing were in fact pleasing. (Quoted in Chadabe, p.269).

I.e Background and experiences

My background as a musician has informed my approach to computer music design in several ways. As well as being an accomplished performer and composer with significant experience in studio engineering, I am also an audio engineer and acoustician. My early musical experience included repairing, making and designing acoustic and electroacoustic instruments. As an undergraduate studying Sonic Art, most significantly with Dr Carl Faia, himself trained at IRCAM, I started the transition from more traditional forms of music to interest and expertise in computer music creation especially the use of Max programming. In free improvisation classes with Dr Jennifer Walshe, it was interesting to combine a new way of thinking about free improvisation with sonic art studies to bypass limitations and boundaries and to develop new ways of thinking and techniques, These included Max programming itself as well as sensors, materials and gestures which allow a new way of making instruments and new forms of musical expression, using different kinds of sensors for the manipulation of sound. The projects discussed in this thesis represent a small selection of the collaborations within my wider research, which has been focused on the development of different kinds of interactive instruments.

I.f Projects under discussion

I.f.1 Chelsea flower show

This project involved the creation of a sonic garden for the 2016 Chelsea Flower Show and was developed in collaboration with the Papworth Trust, Peter Eustance of Symphonic Gardens, percussionist and composer Dame Evelyn Elizabeth Ann Glennie and the Music Department of Brunel University London. The challenge of creating a live electronic soundscape evoking natural sounds and allowing the garden to behave as a musical instrument presented an opportunity to utilise different forms of music technology to create a unique sound design system.

I.f.2 Drama students

This project involved work with postgraduate drama students for their end-of-semester performances in 2016, developing a range of different human Interfaces for computers to augment the students' drama performances through the effective use of sound and interactive music.

I.f.3 Music students

This project involved collaborations with music students at Brunel with further explorations of interactive instruments and the use of a selection of sensors to generate and manipulate sound. In the following chapters, the musical context of each of these individual projects is introduced and a detailed account of the system design is given and evaluated.

The collaborative nature of these three main projects required the continuous exchange of ideas and perspectives with other musicians as well as participation with other art forms and media. This in turn enabled me to explore the potential of interactive technologies and audio applications to push the boundaries of what is possible in performance.

This study also considers the role of the CMD in the collaborative process and discusses different approaches used to enhance artists' performances with appropriate technologies across various media. The resulting programs, objects and Max patches developed as part of this research are not limited to the collaborative work described here but are the result of a much broader exploration of computer music created during my research. I hope that the work presented here can offer a resource for future computer music work by other performers and composers.

Chapter II: The Chelsea Flower Show — 'Together We Can'

II.a Research questions and overview

1. How did my role as CMD enhance the performance through the development of the interactive instrument in this project?
2. What were the different aspects of the CMD's role when collaborating on a project?
3. In what ways did this collaboration promoted innovation in the design of the garden/interactive instruments?
4. In what ways did this collaboration limit and restrictions of collaborative work in terms of innovation in music technology and sound design?

As a team coordinator, I collaborated with Dr Carl Faia, Dr Colin Riley, the Papworth Trust, Peter Eustance of Symphonic Gardens, Dame Evelyn Glennie and the Music Department of Brunel University London. I work with Dr Carl Faia to develop an App that would be able to harness and manipulate the sound created by this when placed in the garden, and would also allow the incorporation of percussive sounds created by Dame Evelyn Glennie as well as natural sounds evocative of a woodland space, as a result the garden became an interactive instrument. This design gave the sense of Dame Evelyn Glennie ongoing live performance during seven days of the show, without her constant presence. There are several aspects that made the garden different from previous or similar projects. The garden itself is mechanical, powered by running water moving the mobile arms which are also remotely and independently controlled. The music technology for the garden involved Max programming that enabled the garden to produce sound automatically or manually for long hours, sometimes with an additional live performer playing percussion instruments based on the music produced by the garden. The expectations and aesthetic sensibilities of the audience and collaborators imposed limits on the new forms of musical expression that the technology made possible in the garden.

The *Together We Can* project at the 2016 Chelsea Flower Show was a collaboration between the Papworth Trust, in partnership with the garden designer Peter Eustance of Symphonic Gardens, the percussionist Dame Evelyn Glennie and the Music and Sonic Art students from Brunel University London.

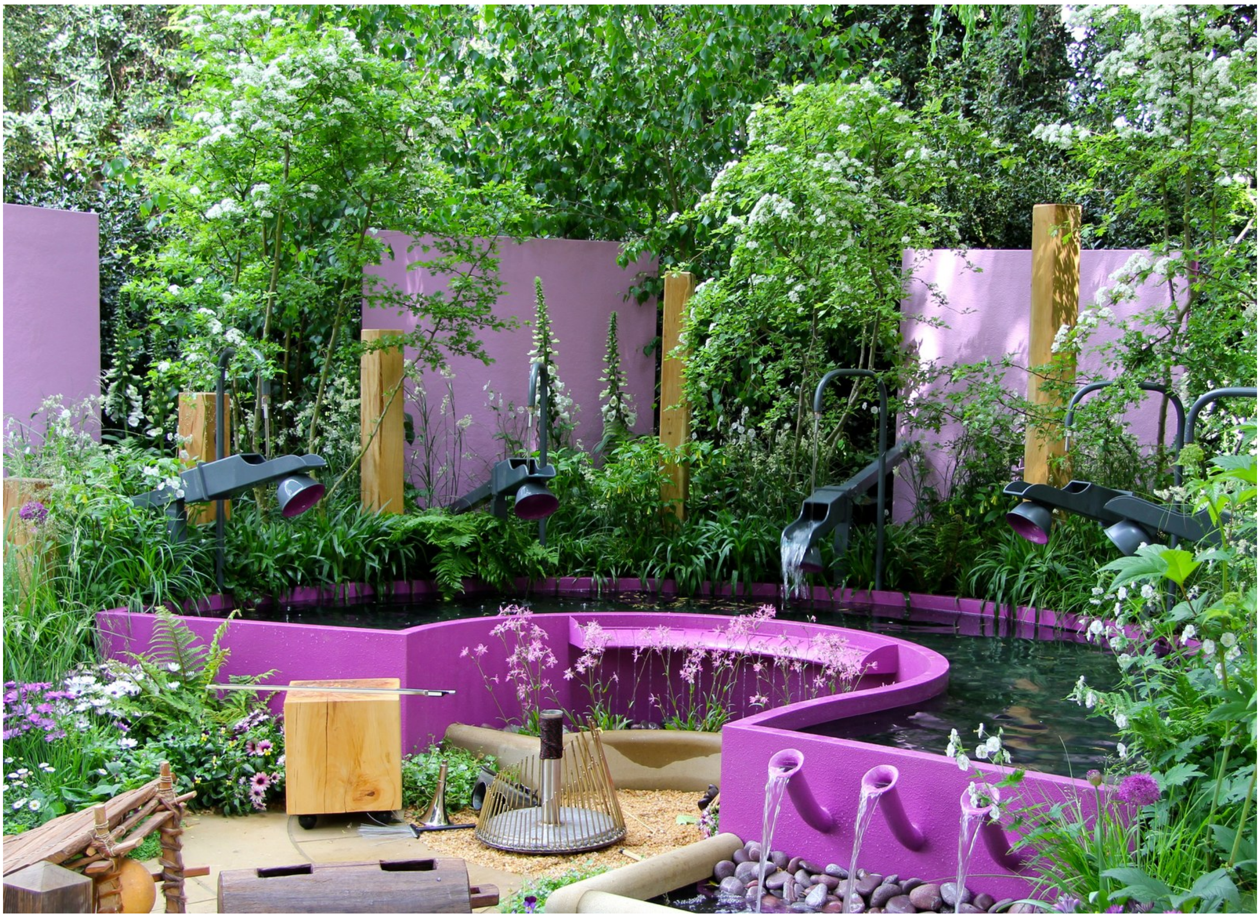

Figure 9. The team set up the garden.[3]

The project aimed to create an interactive acoustic landscape, described by Peter Eustance as having the ambience of ‘an orchestra one would stumble upon in a landscape or a woodland.’ The idea of the installation was to transform the garden into a

[3] Videos available in the documentation part of this thesis, (CFS3, CFS4).

musical instrument, an organic entity that produced, amplified, and manipulated the ambience of the environment and the sound of the performer, Dame Evelyn Glennie.

Figure 10. Dame Evelyn Glennie performing in the garden, Chelsea Flower Show.[4]

The challenge of making the garden into a musical instrument offered many possibilities in terms of innovation. Several recent projects, involving sonic gardens have utilised humidity sensors to create an instrument from a garden environment, such as the St. Horto in Rome, an interactive garden installation designed to combine architecture, nature, music, and social technology. Sonic harps/interactive instruments.

St. Horto, Rome was an idea collaborated by Francesco Lipari, Vanessa Todaro and Federico Giacomarra, which can create in real-time a musical composition by Vincenzo Core. Audio signals starting from a single tune will be worked out automatically according to homothetic principles. The melody reveals itself just through human interaction. Sonic harps, provided with sensors that can detect the touch, are installed in the garden. The same sensors are also attached to some vegetables. If someone touch plant racks, harps or vegetables that will produce notes allowing them to improvise music. By touching once any plant racks, harps or vegetables in a few seconds the garden goes in "resonance" and plays the melody without any manipulation. All sounds are generated in real-time through subtractive synthesis and

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[4] Videos available in the documentation part of this thesis, (CFS1, CFS2).

physical patterns synthesis. The music is then modulated on environmental variables captured by a weather station installed in the garden: the variations in wind speed creates clusters of sounds, the temperature influences the timbre of voices, the humidity changes the sound with echoes and reverberations. (Domusweb.it, 2018).

Figure 11. St Horto, Rome: Collaborative project by Francesco Lipari, Vanessa Todaro, Federico Giacomarra and Vincenzo Core.

These projects are typically developed so that casual visitors can interact with the garden as an instrument regardless of their musical proficiency, whereas the focus of the Chelsea Flower Show was that the percussionist Dame Evelyn Glennie should perform in a garden whose basic layout had been designed before our involvement. Our task was to harness the sounds that could emanate from this garden and to combine them with the performance of Dame Evelyn Glennie.

The Chelsea project was a sound installation like those described by Chadabe in 'Electronic Sound the Past and Promise of Electronic Music', where he refers to a fairground installation project made by Warren Burt in Brisbane:

It was a fairground installation, definitely general public …There was a series of foundation, for example, triggered to spray water as people passed. And there was a sonic fun park. When people put their hands through an empty window frame, they would hear the sound of breaking glass. And there was an optical illusion that made a telephone seem to be where it wasn't. As people approached the telephone, it would ring. And as they reached for it, it would disappear… (Chadabe,1997, p.237).

II.b Implementation - Making sound from the garden

A key challenge in developing the installation for the Chelsea Flower Show was to create a soundscape that combined the performance of the percussionist as well as the natural sounds derived from the garden itself. A second challenge was to maintain a continuous variety and richness of sound and composition over the seven days that the garden was open. Although Dame Evelyn Glennie would perform live in the garden, our task was to enable the garden to perform alongside her as an instrument without her constant presence.

II.b.1 Samples and processing of samples / Max patch

After initially being presented with a map of the basic layout of the garden and an idea for a percussive instrument in the form of a mechanical arm and a block of wood provided by the garden designer Peter Eustance, I worked with Dr Carl Faia to develop an App that would be able to harness and manipulate the sound created by this when placed in the garden, and would also allow the incorporation of percussive sounds created by Dame Evelyn Glennie as well as natural sounds evocative of a woodland space.

In order to capture a variety of sounds derived from the garden, the Brunel students travelled to Lincolnshire to record samples. These recorded samples included various instruments being played in conjunction with the elements of nature. For example, the mechanical arm designed by Peter Eustance was used as a percussive instrument to create a variety of sounds on different materials such as a block of wood covered with various types of cloth. Additionally, the sound that emanated in the water was recorded with JrF D-Series hydrophone microphones.

Figure 12. Sonic Art students recording samples of Dame Evelyn Glennie.

The students took sound samples in their ‘practice garden’, using JrF D-Series hydrophone microphones, JrF C-Series contact microphones and AKG C3000 condenser air microphones in the practice venue as well as during live performances before and during the show.[5]

[5]The (Brunel team 1) video in the documentation part of this thesis is about the session in which Sonic Art students recording recorded samples of Dame Evelyn Glennie. There are two other videos (Brunel team 2 and Brunel team 3) which record the sessions we had in Lincolnshire.

Figure 13. Hydrophone recording of multiple instruments played underwater.

The team strategically placed twelve JrF C-Series contact and JrF D-Series hydrophone microphones in hidden areas of the garden (underwater and behind plants and structures such as the mobile arms) to give listeners the full experience of the vibrant accomplished interactive garden. For example, contact microphones were attached to the arms in specific places or were connected to inverted flowerpots that served as bells.

In order to use these sounds as a part of an ongoing composition, several sound editing and effects sub-patches by each student were incorporated into the main Max patch. Subsequently, the prerecorded material was threaded into their samples for the sonic composition Max patch.

Other recordings included Dame Evelyn Glennie playing water drums, wooden bowls on materials such as hay, and a gong submerged in water just after being struck and then recorded with hydrophone microphones. The idea was to marry the sounds of nature with the new sounds that the performer created. After everything was recorded, all the recordings were edited and manipulated to become new compositional elements.

II.b.2 Sound spatialization and technical rider introduction

Sound spatialization has led to a redefinition of the relation between a musical work and the space in which it is performed. The result of this is a new relationship between the work, the performer and the audience. Overall there were ten loudspeakers and two subwoofers (two sets of Logitech Z906 Surround Sound 5.1 Speaker System) and additional studio speakers (a pair of Fostex PM 0.4 active monitor speakers), five JrF D-Series hydrophone microphones, seven JrF C-Series contact microphones for the garden, four contact microphones for the performer, two MOTU interfaces (MK3 and 828 MK3) and one MacBook Pro with Max patch, all connected to make the sound of the garden. An additional MacBook with a different Max patch was used for the two days when Dame Evelyn Glennie was performing with the garden. As the speakers needed to be protected from the rain and the watering of the garden and plants, the team decided to make fibreglass boxes for each speaker to shelter them, (There is an image of the fibreglass boxes and speakers in figure 39 of the appendices).

This technology enabled the garden to produce composed sounds, both randomly or specifically, sending the audio outcome to multiple speakers in timings specified automatically or manually, so that the audience could experience the sound as a moving physical presence along with the space and the garden.

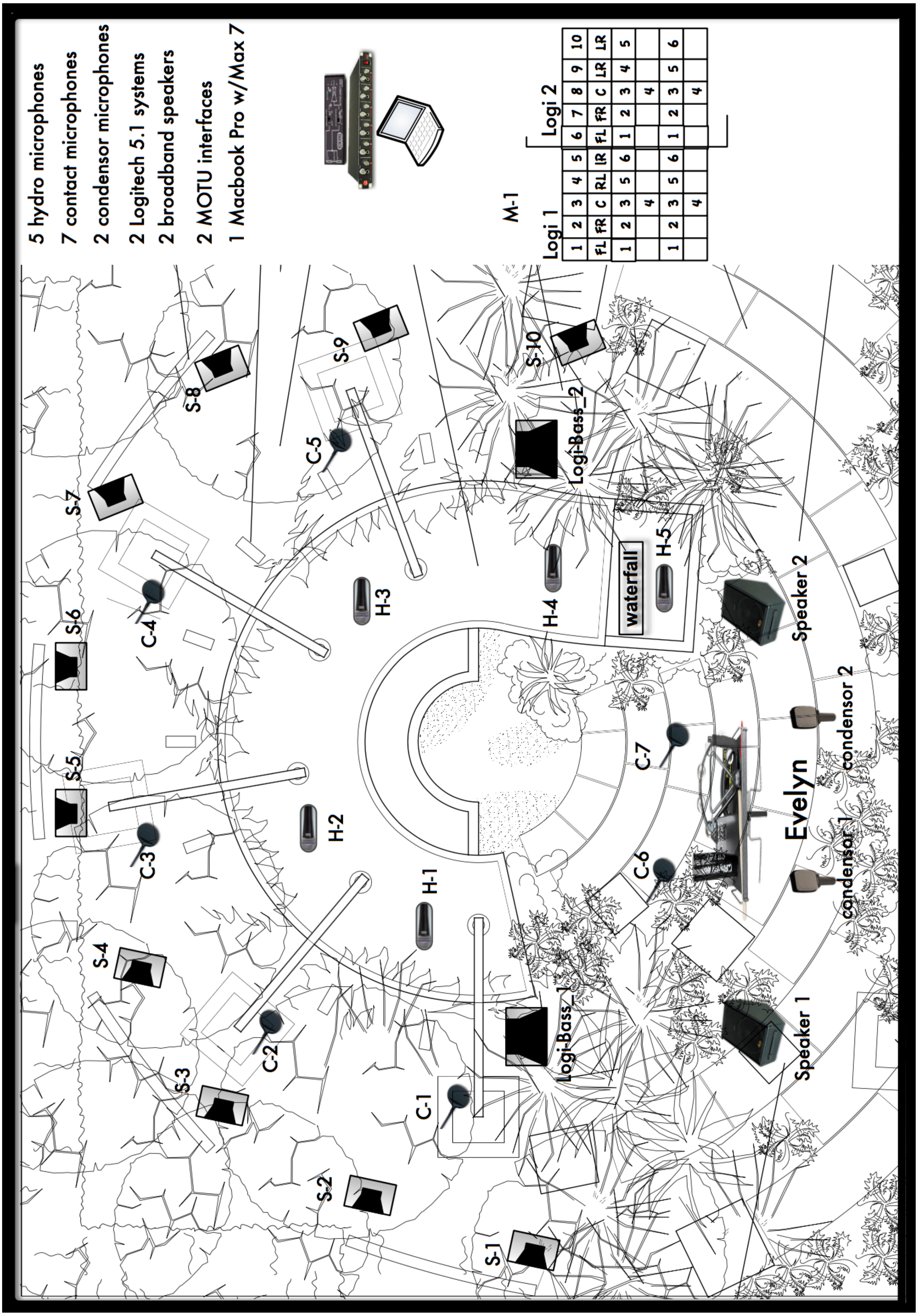

Figure 14. The technical rider of the Chelsea Flower Show created by Dr Carl Faia.

Figures describing Max patch

Overall, the garden was comprised of several different processes as described in the figures below. To achieve the full experience, we made eight Max patches or sub-patches, which were ultimately combined into one Max patch by the end, for the show.

Figure 15. JrF D-Series hydrophone microphone on the left and JrF C-Series contact microphone on the right used for the Chelsea Flower Show.

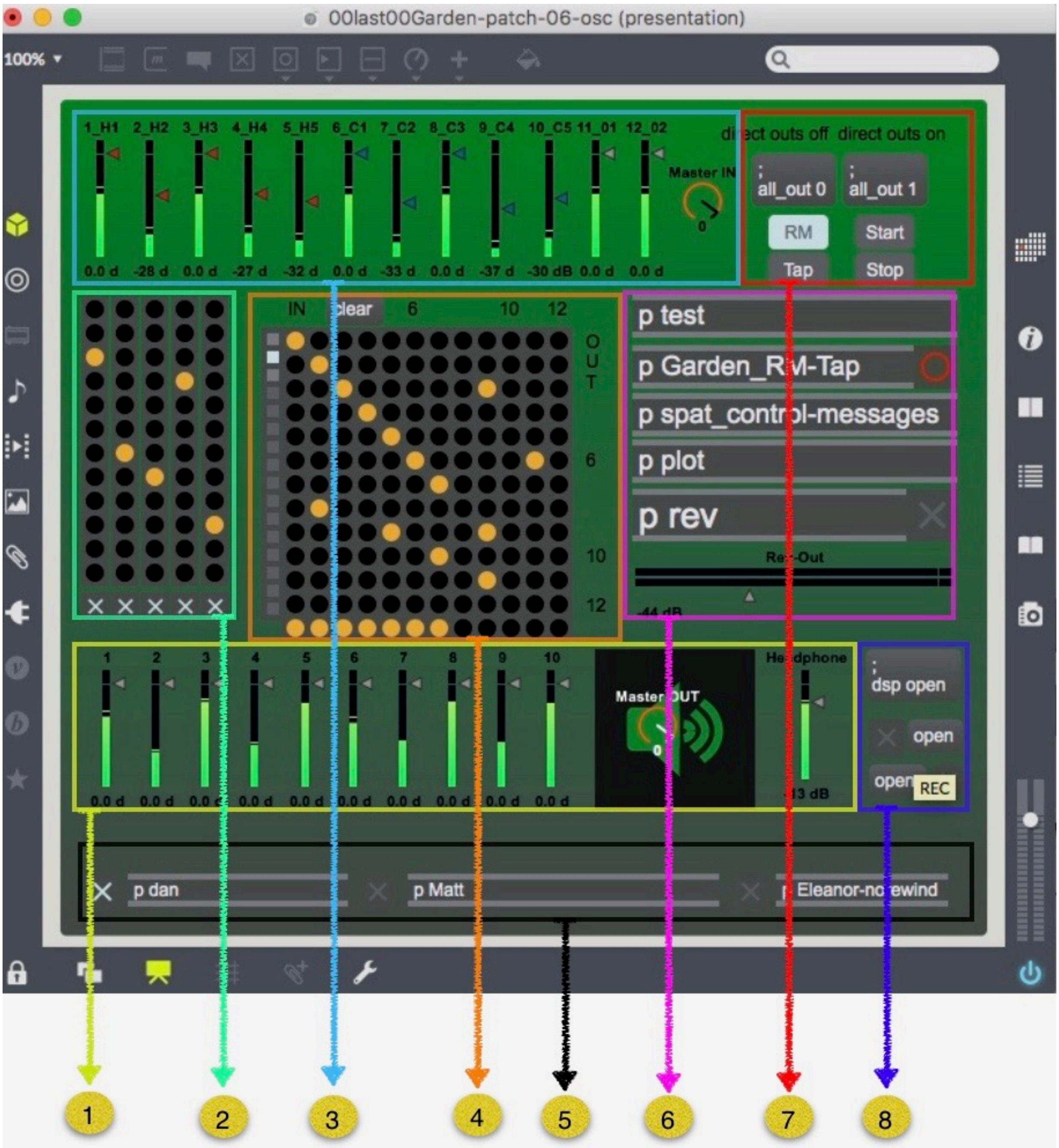

Figure 16. Final Max patch created for the Chelsea Flower Show.[6]

Figure Explanation

Figure 16.1. Main outputs amplitude.

Spatialization: main outputs, 10 channels manual or automatic. The functions of this segment of the panel are amplification, the switching would on/off the whole audio process of the Max patch, a headphone output for the person controlling the Max patch, and a master output control with one knob. The ten outputs for loudspeakers and two

[6] Final Max patch is available in the documentation part of this thesis, (CFSPatch).

subwoofers were placed in different parts of the garden and were controlled by panels two and four in this figure. It was possible to set them to produce sound randomly or to control the specific timings automatically or manually. In this way, the audience could experience the sound in different ways such as a moving physical presence.

In *The Theory And Technique Of Electronic Music* Miller Puckette claimed that:

> The most fundamental property of a digital audio signal is its amplitude. Unfortunately, a signal's amplitude has no one canonical definition. Strictly speaking, all the samples in a digital audio signal are themselves amplitudes, and we also spoke of the amplitude for digital audio signals in general. (Puckette 2007, p.3).

Figure 16.2. Random output machine.

This random outputs generator was designed to control the outputs audio amplitude level and timing of the sub-patch (p test in figure 19.6), in a specific time or random automatically, or as manually preset messages.

Figure 16.3. Inputs.

This part of the Max patch was designed to control the amplitude of the audio inputs from all the microphones in the garden.

Figure 16.4. Matrix.

Here the Max patch controlled which audio inputs and outputs should be used; specifically, which audio inputs should go through which outputs. It was possible to control the matrix randomly or in a specific time automatically or manually by having different presets. Clicking on the dots on the matrix determined which input microphones connected to which outputs.

Figure 16.5. Additional students' sub-patches.

The three sub-patches from the students were controlled individually because if two or more were activated then the outcome audio result would be distorted or very chaotic.

Figure 16.6. The sub-patches.

As well as the three student sub-patches there were five more sub-patches. The first one is the p test: a sub-patch that contains ten SF-play (Sound File-play) objects (prerecorded samples) that have been used to play some prerecorded sound and music composition based on Dame Evelyn Glennie's instruments and the garden sound. It was possible to control/play different sound files which have been composed by all the team members from the garden or Dame Evelyn Glennie's instruments and loop and mix them with the live sound of the garden. This could be described as free improvising with prerecorded sound, along with the garden sound it made the final outcome of the whole garden richer.

The second sub-patch in this panel was the p Garden_RM_Tap which was used to control the incoming sound from all the microphones into the Max patch at different times automatically by saving preset message objects which were also accessible from the third sub-patch in this figure (p spat_control-messages).

The fourth sub-patch (p plot) in this panel was a live technical rider (map/plan) of the whole equipment in the garden and is explained in more detail in figure 19.2.

The fifth sub-patch in this panel (p-rev) controlled the reverb by using the fader under the sub-patch.

Figure 16.7. Another automatic control centre.

This part of the Max patch controlled the incoming audio from the twelve microphones and controlled the amplitude of all income audio to the Max patch at a random or specific time. It worked with what was happening in the two sub-patches (p Garden _RM-Tap and p spat_control-message) in panel six controlling how loud the microphones were.

Figure 16.8. DSP and Recording.

This part controlled the interfaces for DSP control, it recorded the audio of anything happening in the Max patch by recording the outcome audio to AIFF files format at the end of each day.

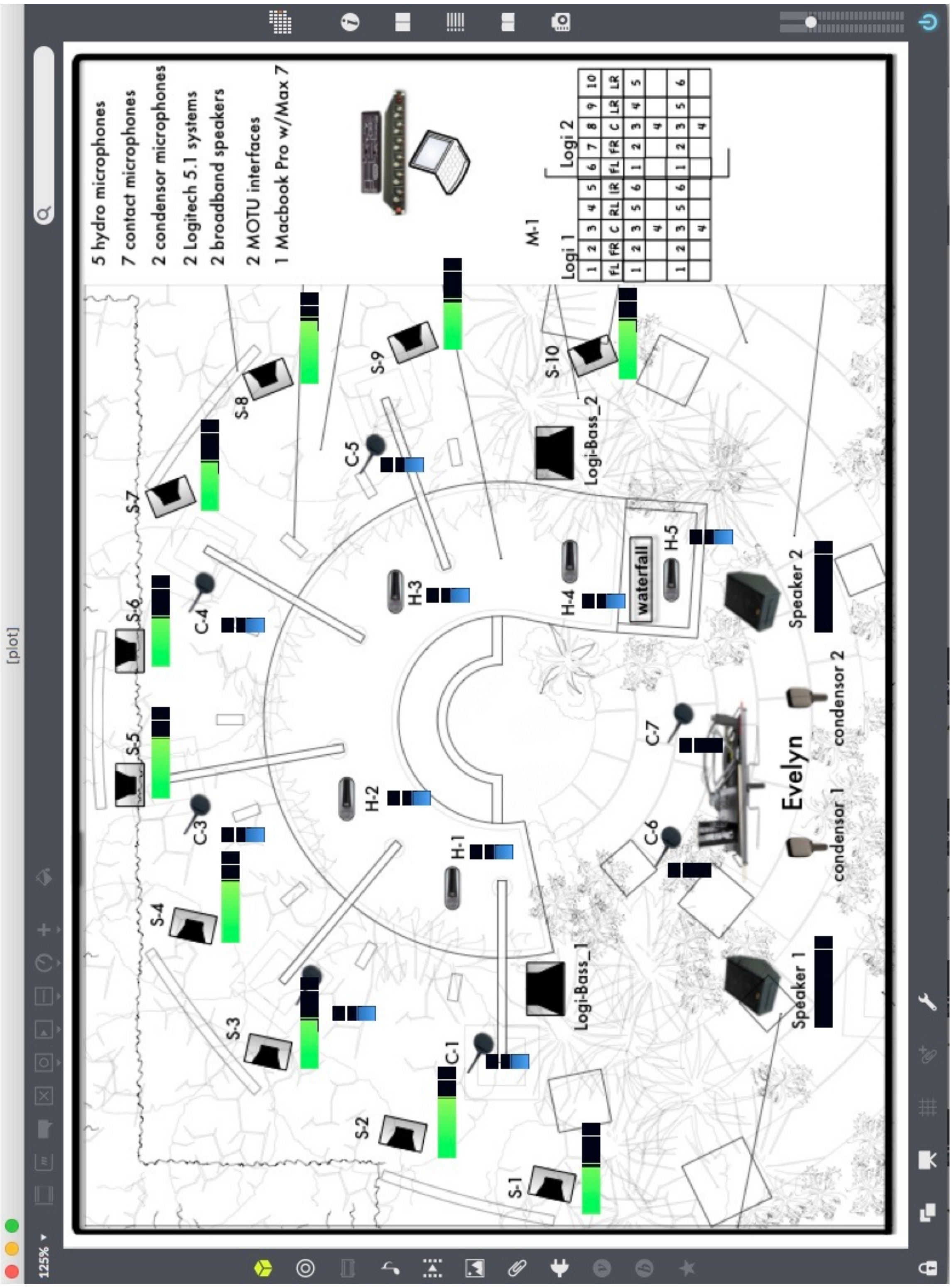

Figure 17. Technical rider as a sub-patch.

Figure Explanation

The Tech-rider sub-patch was designed to provide a visual map of everything happening in the garden for different purposes such as inputs, outputs and live sound.

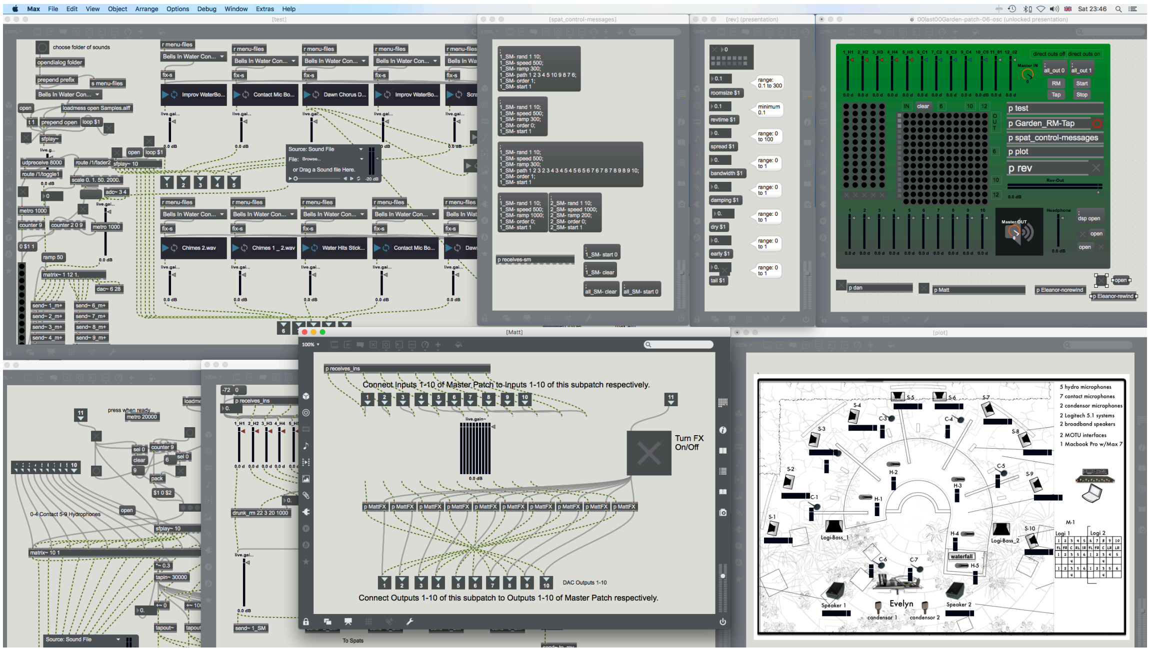

Figure 18. All eight sub-patches including the main Max patch, (Nine overall).

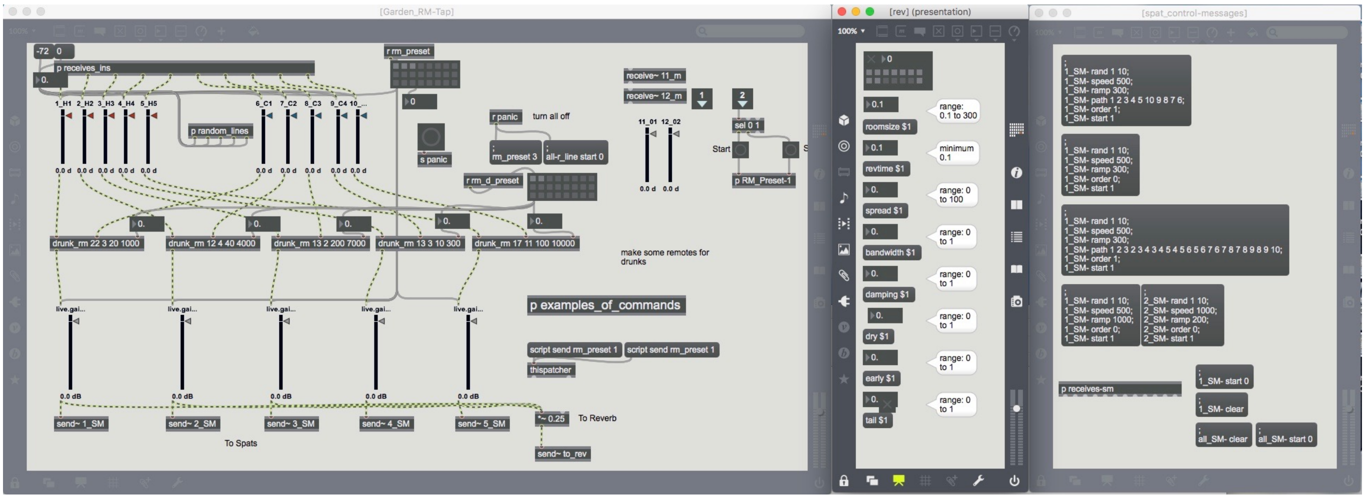

Figure 19. The sub-patch I used most often for composition and improvisation/ experiment during the performance.

Figure Explanation

The sub-patch in the middle was named the P-rev in panel six and is a Gen jitter reverb object. This was one of the most effective sub-patch because unlike others it produced no buzzing or clicking during the performance when changing any number/ DATA in relation to the different type of effects of reverb existing in this sub-patch.

II.c Conclusions

In relation to the research questions

1. How did my role as CMD enhance the performance through the development of the interactive instrument in this project?

The garden became an instrument, allowing the audience to immerse themselves in the sound of the garden. This design gave the sense of Dame Evelyn Glennie ongoing live performance during seven days of the show, without her constant presence, by sampling her performance on a variety of percussive instruments before the show, alongside samples taken from the garden.[7]

The questions that Atau Tanaka raises about these new instruments, such as what is composition/performance, where does the instrument begin and end, and who is the performer, are therefore very pertinent to this project. While the instrument, as a whole, was designed in a way that would allow it to function as a stand-alone instrument without the need for human intervention, the sounds being processed were continually composed and performed by the CMD who was hidden from public view behind a screen at the back of the garden. As Dr Carl Faia observes, there is a 'tendency to underplay or minimize the breadth of the role of the CMD itself, especially in regards to public presentation'(Faia, p. 8).

2. What were the different aspects of the CMD's role when collaborating on the project?

[7] Audio File is available in the documentation part of this thesis, (CFS).

The CMD's role is complex and multiple: technician, composer, performer, and mediator. As Laura Zattra explains in *Live Electronic Music:*

> In this context, terminology will also have to be taken into consideration. The emerging profession presented in this chapter has been described and defined in different ways over the years: musical assistant, technician, tutor, computer music designer, music mediator (Zattra 2013), klangregisseur, live electronics musician, digital audio processing performer (Plessas and Boutard 2015). (Sallis et al., 2018. p. 61).

As a team coordinator, I collaborated with Dr Carl Faia, Dr Colin Riley, the Papworth Trust, Peter Eustance of Symphonic Gardens, Dame Evelyn Glennie and the Music Department of Brunel University London. There was also much discussion with Dame Evelyn Glennie concerning the sound material, interactive elements and overall architecture of the installation. (see Appendix A, 'Chelsea Flower Show Documents').

3. In what ways did this collaboration promote innovation?

There are several aspects that made the garden different from previous or similar projects. The garden itself is mechanical, powered by running water moving the mobile arms which are also remotely and independently controlled. The music technology for the garden involved Max programming that enabled the garden to produce sound automatically or manually for long hours, sometimes with an additional live performer playing percussion instruments based on the music produced by the garden.

4. In what ways did this collaboration limit and restrict collaborative work in terms of innovation in music technology and sound design?

The expectations and aesthetic sensibilities of the audience and collaborators imposed limits on the new forms of musical expression that the technology made possible in the garden.

Chapter III: Collaborative projects with MA Drama students

III.a Research questions and overview

1. What were the limitations and challenges of this collaboration and what future possibilities were opened up by this collaboration?
2. What comprised the instruments developed as part of this project?
3. What impact did the specific context of this collaboration have on the development of the instrument/installation, how was technology adapted to enhance performance, and what was innovative about the solutions found?

I collaborated with MA Drama students (Alistair Daniel-Guy, Luay Eljamal, I-Hsuan Chen, Haein Song, Hongye Deng) on several theatre projects alongside Dr Carl Faia, Professor Johannes Birringer and Graeme Shaw, and assisted with their end-of-semester live performance. I collaborated on students' performance propositions by adding physical computing technologies designed to suit the specific needs in their chosen format, In particular, I made Max patches, recording, editing, rehearsing and troubleshooting hardware, software devices and applications such as sensors, Arduino, Kinect, tablet with Mira, Max, Ableton Live, microphone for live tracking and Touch OSC. I researched a range of subjects and technologies, including human interfaces for computer and general usage, the usage of sensors and other devices for the capture of gesture and control of computer programs and the use of cameras or similar technologies to input visual information to computers.

Figure 20. Collaboration with MA Drama students.

I attended tutorials with Dr Carl Faia and the MA students on their projects for the advanced theatre module “Exploring Specialist Option”. This module is designed as a series of highly focused workshops in advanced theatre techniques and the final project is a live performance using technology. The experience and technical expertise of the students varied widely, presenting an interesting environment to explore the limits of the role of the CMD. I prepared by researching a range of subjects and technologies, including human interfaces for computer and general usage (such as joysticks, keyboards, mouse and pointer devices), the use of sensors and other devices for the capture of gesture and the control of computer programs, and the use of cameras or similar technologies to input visual information to computers.

Examples of physical computing include game-style joysticks/controllers, Wii controllers including add-ons, Kinect camera systems with skeletal tracking, LEAP Motion, EoBody interfaces as well as customised uses of various sensors, Arduino/ Raspberry Pi cards (also with sensors) and simple video cameras attached to the computer for human interfacing. We also used smartphones and tablets with complex sensors onboard to control a computer and Max patch, as well as pitch and envelope tracking from instruments or available sound.

Several computer programs were used in collaboration with the students, including Processing, Pure Data, Isadora, Max. I responded to the students' performance propositions with technologies designed to suit the specific needs in their chosen format (dance, theatrical performance, multimedia, etc.). In particular, I made Max patches, recording, editing, rehearsing and troubleshooting hardware, software devices and applications such as sensors, Arduino, Kinect, tablet with Mira, Max, Ableton Live, microphone for live tracking and Touch OSC.

I found it enlightening during this collaboration to working with the students' feedback and to reflect on the process as a whole. From this, I was able to adapt how I connected or mixed all the sounds and images, devised a technical setup and proposed appropriate technology. I needed to imagine the performer on the stage in my mind and identify any problems before rehearsing or performing the piece. Working closely with their desired outcomes and feedback allowed me to anticipate and predict problems and solutions.

In part, the collaborations needed to have individualised setups for each performer to shape and expand the outcome of the performances, such as customised Max patches, specific recording and editing of sound, rehearsing with sensors, using various images in prerecorded and projected video and sorting technical issues related to hardware and software devises and applications.

The first two performances described later in this chapter (the projects of Alistair Daniel-Guy and Hongye Deng) use Arduino and sensors. For both performances, the same set of sensors were hidden on stage. The FSR (force sensitive resistor) sensors were positioned and hidden on the floor for one performance and then moved to the table for the next. For Hongye Deng, the FSR sensors were taped to the floor and placed around the space where the performer moved around and activated them to play prerecorded material. For Alistair Daniel-Guy's, the technology was hidden under a table during a set change and the same Max patch used with Alistair Daniel-Guy's sound files. The third performance described is I-Husan's project. I showed her a few different ways of triggering sound and she decided to use a tablet for her performance which then was connected wirelessly to the Max patch, through Mira, that I created for her.

For each performer, I needed to think of multiple methods to trigger a sound that would depend on the performers' choices. I needed to show them the options and possibilities of working with different technology/gestures and let them experiment with these technologies to find the one which best suited their performance. The skill of the CMD lies in assessing what will work best for the performer and enables them to be comfortable with the setup.

It was also necessary to consider what would be seen during the performance and the parameters of the stage or performance space. In *Digital Performance* Steven Dixon refers to the work of Mark Coniglio:

> As early as 1989, Troika Ranch's artistic director Mark Coniglio developed the group's wearable hardware movement sensing system *MIDIDancer*, which sends wireless MIDI signals to the computer. It uses flex sensors attached to the dancer's joints (elbows, knees, wrists, hips, and the like), which are attached by wires to a single-chip microcomputer in a small box usually worn on the dancer's back. The computer measures the degree of "flexion" of each joint thirty times per second, assigning it a

number between zero (straight) and 100 (fully bent), and transmits the information via radio waves to an off-stage receiver/microcomputer. This checks for errors and ignores any corrupted information before sending MIDI signals to a Macintosh computer running software that "intelligently interprets" the data and triggers technical cues and manipulates media from files stored on a hard disc or Laserdisc, or from the input of a live video camera. (Steve Dixon, p.197).

In fact, the performer as a generative source has always been an attractive creative idea:

Coniglio recalls how 'I had been writing a lot of dance music, and had simultaneously become very interested in live interaction- the combination of these two interests resulted in my desire to have the dancers directly generating music from their movement.

Today something that was once a highly complicated approach in interactive and collaborative creative projects has become simple enough that MA students in a few weeks can explore this space in collaboration with a CMD.

III.b Implementation

III.b.1 Arduino and sensors (Alistair Daniel-Guy and Hongye Deng).

I had individual meetings with Alistair Daniel-Guy and Hongye Deng before the performance and I attended their end of semester performances. Even though each of them had separate and highly personal performances, the technologies involved were very similar.

To set up for their performance, there were six FSR sensors attached to twelve-meter cables were connected to the Arduino board. This allowed gestural data to be transmitted to the computer and the Max patch. The sensors were built from scratch specifically for the performances. For the sensors to be compatible with the performance I customised each one by soldering the ends of the sensor wire to a soldering board.

I also created the Max patch specifically for the performances and the customised sensors. In both of the performances, the objective was to play the different soundtracks from the Max patch triggered by the sensors and to do this, Alistair would press the different sensors which were hidden under a table. The sensors then played his pre-recorded voices. Hongye Deng's performance was a dance piece and the sensors were on the floor so every time Deng wanted to play a different soundtrack she would trigger the sensors by stepping on them. While very different in aesthetics and approach both these projects used well-defined placement of sensors to produce a performance otherwise impossible to imagine. This also entailed creating choreography for triggering and controlling the computer that then became an integral part of the performances.

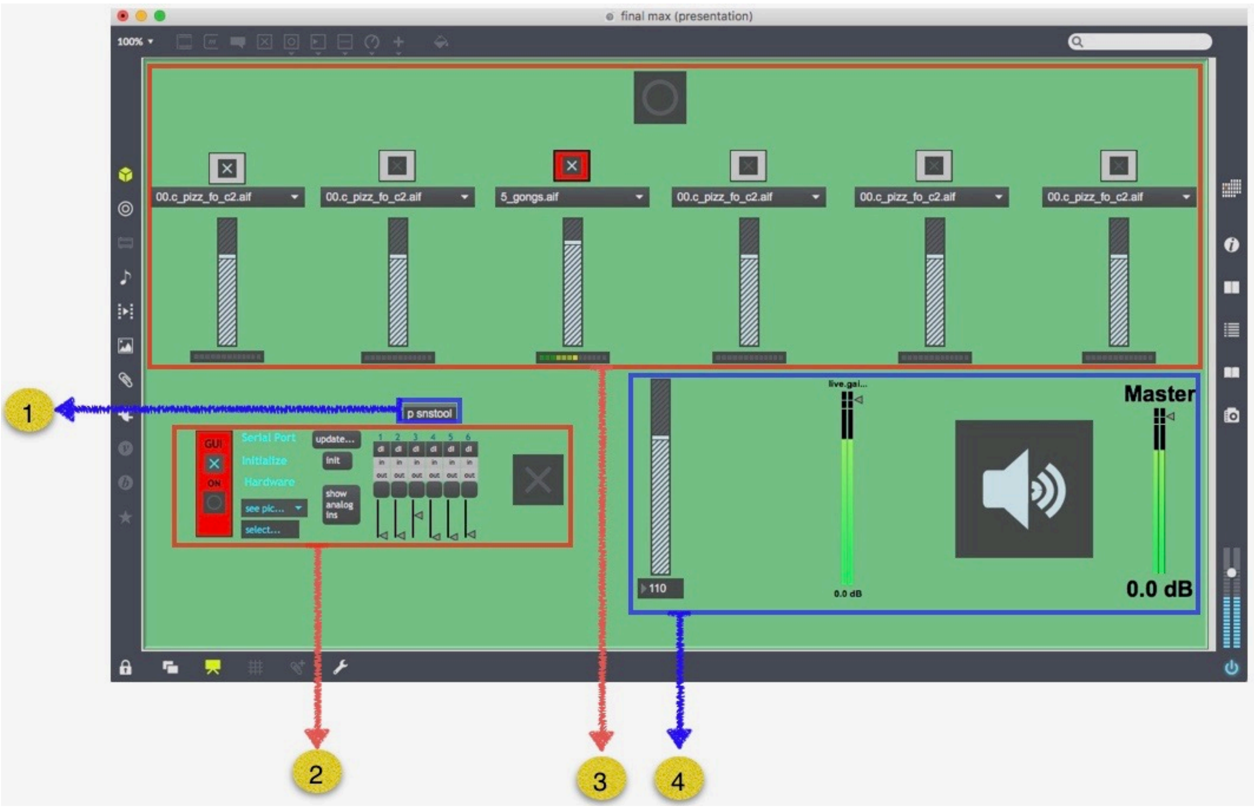

Figure 21. Final Max patch created for Alistair Daniel Guy and Hongye Deng for their performances.[8]

[8] Final Max patch is available in the documentation part of this thesis, (Hongye& Alistar).

Figure Explanation

Figure 21.1 Sensor income data smoother sub-patch.

By having this sub-patch within the main Max patch it is possible to control the sensors' incoming data. To use the sensor data it was necessary to create a process to filter unwanted data and to smooth and correct the information being received by controlling four major aspects of the incoming data:

1. "Slide" object: smoothes the values logarithmically and filters an input value logarithmically between changes. It is also useful for enveloping and lowpass filtering to smooth the incoming stream of data from the six sensors.

2. "Split" object: filters a range of numbers from the incoming data. With this object, it is possible to check if data streams fall within a specified range and then direct this data to the first outlet while passing unwanted data to the second outlet for further treatment.

3. "Speedlim" object: controls the speed of the incoming data to a fixed time limit specified in milliseconds or a tempo-relative interval.

4. "Scale" object: maps incoming data to the required output range. In general, the scale object maps an input range of float or integer values to an output range.

Figure 21.2 Arduino and sensors control.

This part of the Max patch is designed to activate the Arduino board and sensors within the Max patch to start receiving data from the sensors.

Figure 21.3 AIFF of pre-recorded and edited sound, play by triggering of the income data from sensors.[9]

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[9] Audio files are available in the documentation part of this thesis, (HongyeAIFF 1 to 5 & AlistarAIFF 1,2).

In this part of the Max patch, it is possible to open a folder of Audio files/samples/sound/AIFF to play during the performance. In this case, performers may use FSR sensors to activate/play different audio files during their performances. There are six faders/gains to control the amplitude of the audio files.

Figure 21.4 Main outputs.

This is the master audio out control sending all audio channels to four loudspeakers.

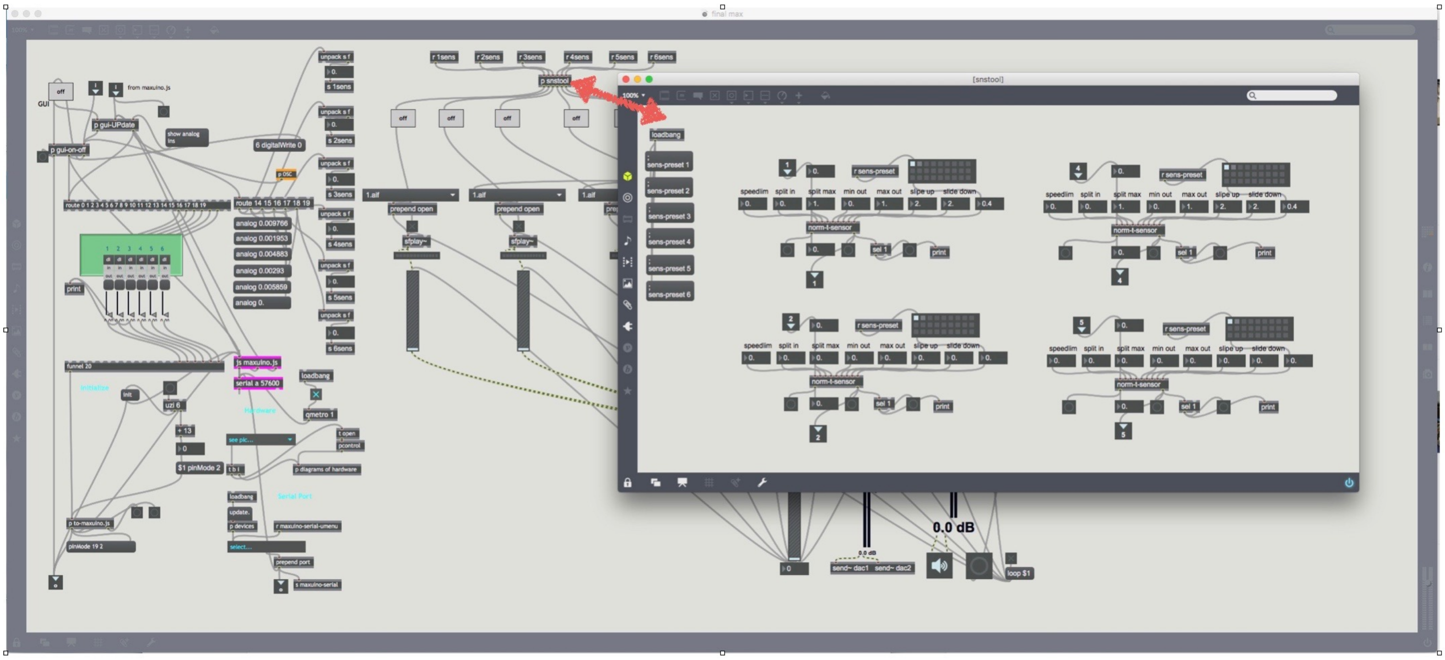

Figure 22. Sub-patch for Alistair Daniel Guy and Hongye Deng Max patch.

Figure Explanation

The red arrow shows the B-Patcher or sub-patch which is opened on the right side of the red arrow. In the open window is the place in the Max patch where the sensors' incoming data is smoothed, controlled and analysed to give the specific income data (rather than buzzing and unwanted data) to control the Max patch. This part of the Max patch is like a tap attached to a water pipe to manipulate the water pressure, (See figure 24.1, Sensor income data smoother sub-patch.)

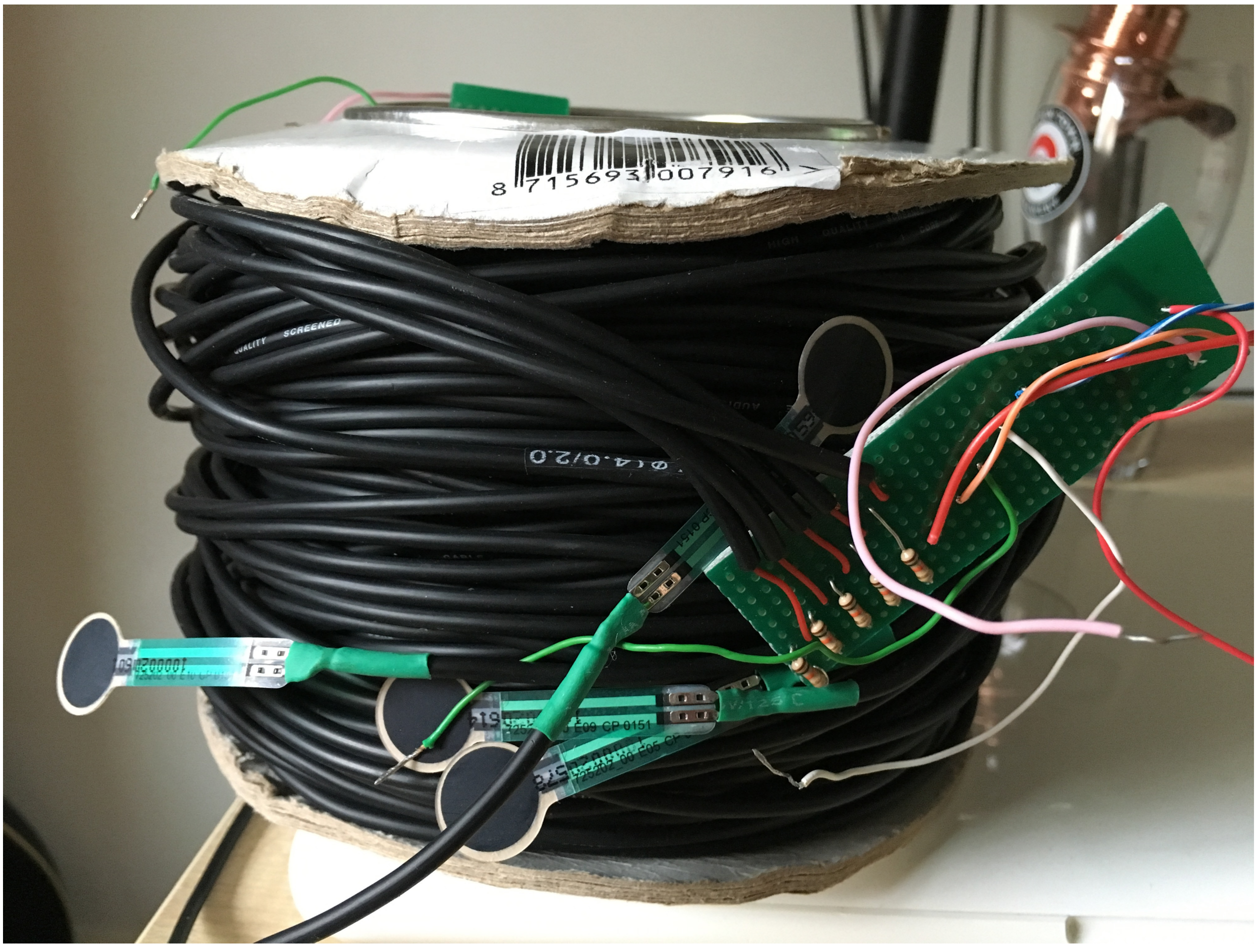

Figure 23. Six FSR sensors for Alistair Daniel Guy and Hongye Deng.

Figure Explanation

Six FSR sensors connected to twelve-metre cables are soldered to a soldering board which makes it easier and more reliable to connect to an Arduino. These sensors then can be attached to different surfaces.

III.b.2 Max patch, Mira, Ipad, I-Hsuan Chen (Dear Rose)

For I-Husan Chen I used an iPad mirroring the Max patch to playback twenty-two different recordings[10], She used the iPad to play the recordings wirelessly from a hidden iPad on a table during her performance.

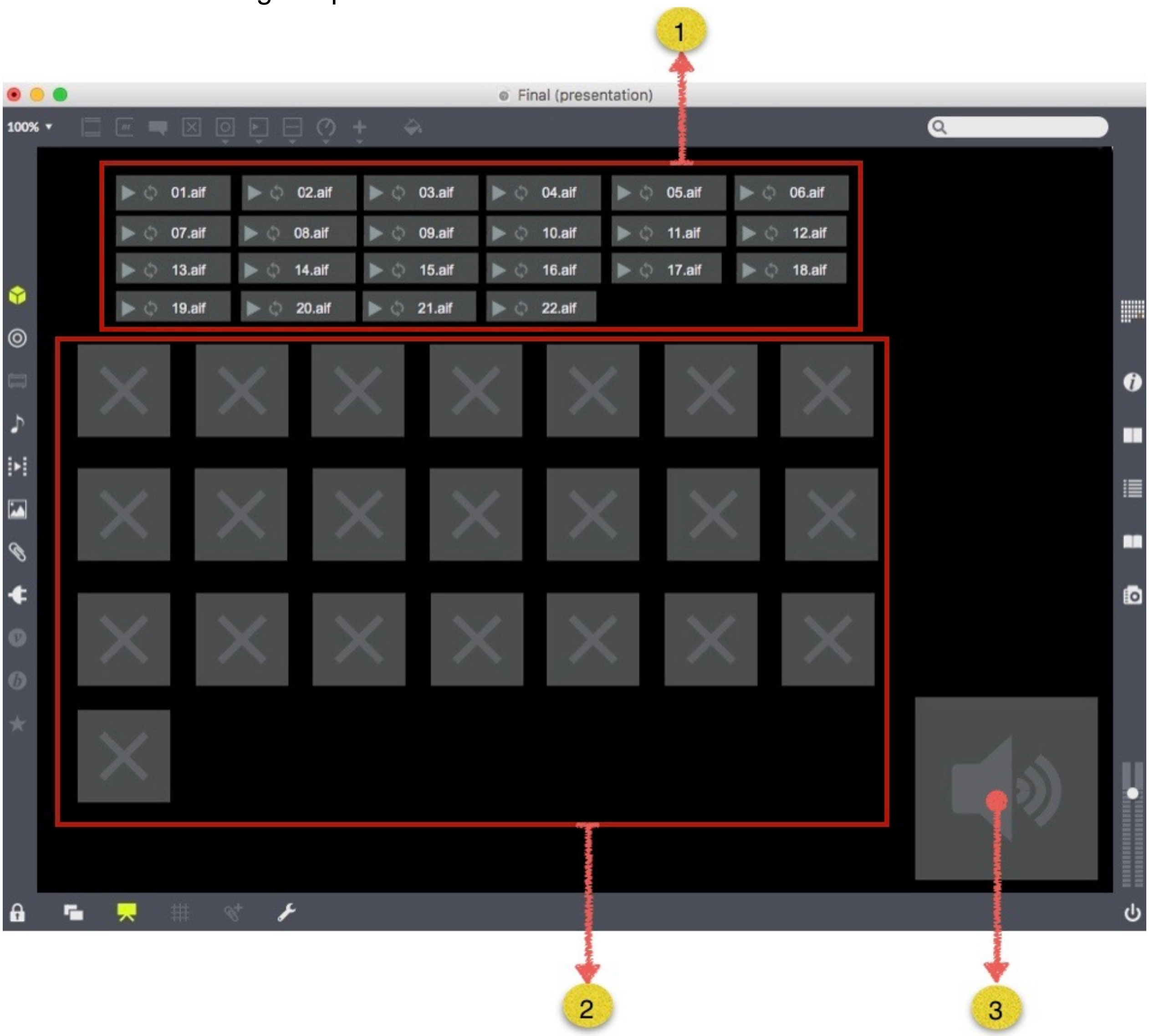

Figure 24. Final Max patch created for I-Hsuan Chen for her performance.[11]

Figure Explanation

Figure 24.1 Pre-recorded sound.

These are the prerecorded sound materials: mainly her speaking voice.

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[10] Audio files are available in the documentation part of this thesis, (I-HusanAIFF 1 to 23).

[11] Final Max patch is available in the documentation part of this thesis, (I-Husan).

Figure 24.2 Buttons.

There were twenty-two buttons for each track, triggered by pushing them on the tablet hidden on the table.

Figure 24.3 ON/OFF sound.

This shows the mirroring from Max patch to the App Mira on the iPad, hidden on the table during her performance.

III.c Conclusions

In relation to the research questions

What are the unique challenges of being a CMD and working on Drama?

1. What were the limitations/challenges of this collaboration and what future possibilities were opened up by this collaboration?

2. What comprises the instruments developed as part of this project?

3. What impact did the specific context of this collaboration have on the development of the instrument/installation; how was technology adapted to enhance performance; what was innovative about the solutions found?

During this collaboration, I adapted and innovated a range of technologies to suit the students' needs in their respective media. My key involvement encompassed making Max patches, recording, editing and rehearsing, troubleshooting hardware and software devices and applications (sensors, Arduino, Kinect, Tablet, Mira, Max, Ableton live, Microphone, Touch OSC). As I mentioned before it was striking how what were once highly complicated approaches in interactive and collaborative creative projects have become simple enough for users to explore in collaboration with a CMD.

These questions will be answered in more detail in the final conclusion of this thesis.

Chapter IV: Collaborations with Brunel Music students

IV.a Research questions and introduction to the work, overview

1. What were the limitations of this project?
2. What were the instruments comprised of that were developed as part of these projects?
3. What impact did the specific context of this collaboration have on the development of the instruments/installations, and how was technology adapted to enhance performance?
4. What were the limitations/challenges presented by these collaborations, and what future possibilities were opened up by this collaboration?

The pedagogical function of the projects with music students mostly involved introducing different types of sensors and showing the students how they can interact with them through different programs. For these projects, my supervisors and I decided to make a basic introduction to different types of sensors, such as the sensor box for the free improvisation class. In other projects, the performers needed more specific technologies such as a pedal for Matt London's Shard, or a webcam for Sara's project to control and manipulate different parameters inside the Max patches, or for the clock tower project with Stephen where piezoelectric microphones/contact microphones were attached to the frame of the clock and the bell. All these projects involved a considerable amount of hardware with many hours of software programming, experimenting and exploring compositional techniques.

An important aspect of using sensors is that it is possible to have full control of the incoming data in the Max patch, scaling, converting or mapping the data in any way necessary. These data can be connected and related to many other programs, objects, movement or other factors. This project allowed the development of a unique interactive instrument without the usual constraints of collaboration.

I had several collaborations with members of the Brunel Music department. With PhD student Matt London, I made *Shard* a development of a Max patch for baritone saxophone and live electronics; with Masters student Stephen Shiell I made an installation for Hackney Clock Tower using contact microphones, spatialization and Max; for Sara Belle, I developed colour tracking and introduction to Max for her final project; for Dr Jennifer Walshe I designed a bespoke sensor box, the Kraken, designed for her free improvisation class.

During my research, I attended Jennifer Walshe's free improvisation classes. After discussion with Dr Walshe, I made a sensor box that had several types of sensors including two different light sensors, a temperature sensor, a bend sensor, a pressure sensor, a knob sensor and a contact microphone attached to the box. This sensor box could be connected to existing Max patches enabling the students to control certain factors of sound such as frequency or pitch through the sensors.

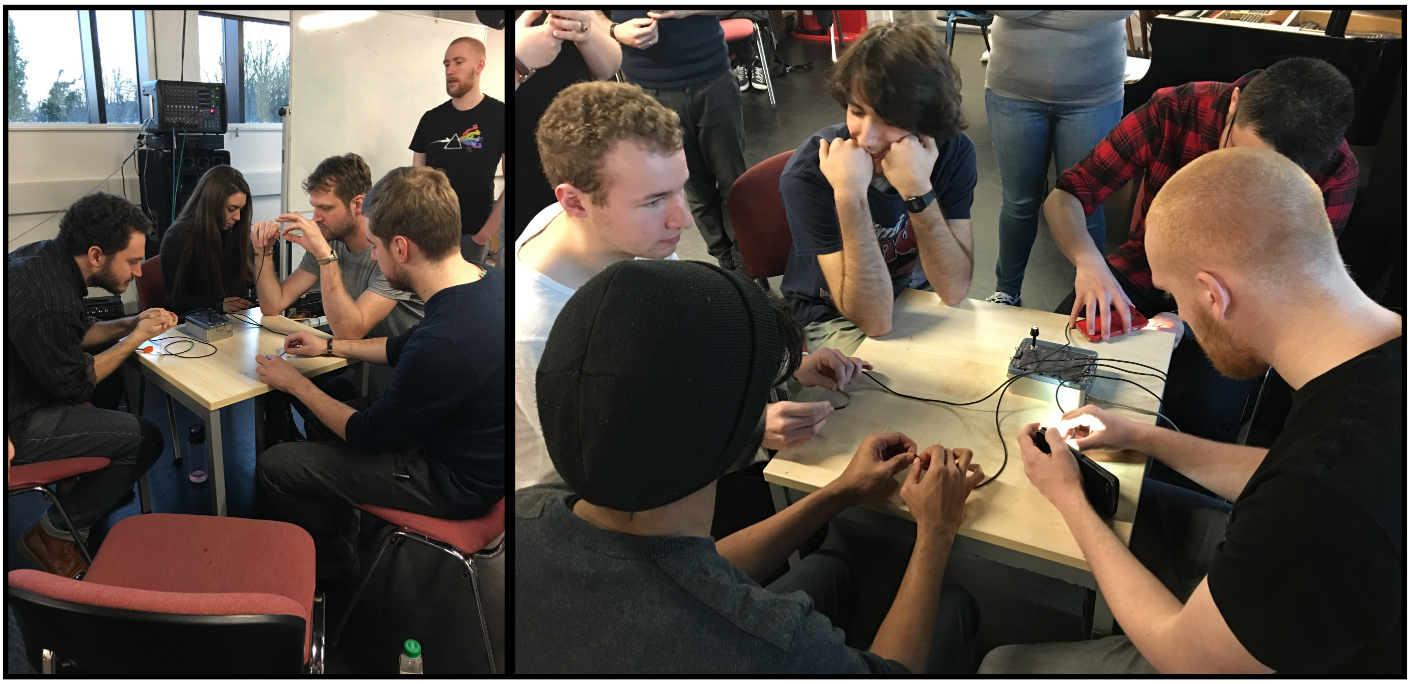


Figure 25. Free improvisation class and the sensor box.

Dr Jennifer Walshe and I wanted to use the sensor box to teach students how to think about improvising with electronics rather than programming Max software, which can be intimidating. We also wanted to teach the students how different types of sensors work. The aim of this set-up was pedagogical. The student could play with the sensors and Max patch in the second class and if they were interested in working with them I would then collaborate with them to make their own boxes, Max patches or sensors depending on their different needs.

Figure 26. Dr Carl Faia and Music MA student's end of semester projects.

This work allowed for research to be done in the use of sensors and instrument making. Max Mathews says of working with sensors that: 'one has to think of overall systems to get a musically useful thing, you can not develop a sensor without relating it to the programs that you are going to use it with.' (Chadabe,1997, p.230). The work with the students helped define this aspect of my research into sensors and Max programming. The box created for this project is still in use and can be easily connected for both pedagogical purposes and creative projects.

PhD student Matt London already had a max patch for his piece *Shard,* for amplified baritone saxophone and live electronics, but it needed to be updated and many objects and parameters within the patch needed to be changed or fixed.
During previous performances of *Shard*, Matt had a foot-switch pedal to trigger different parameters inside the Max patch but he no longer had the pedal.

After examining the old Max patch, I recommended that we create a new Max patch, but he wanted to keep the old patch as he was comfortable and familiar with it. Subsequently, he and Loré Lixenberg performed solo versions of *Shard* at the old church in Stoke Newington[12], London, and Matt asked me to make the Max patch work without somebody there to control it during the performance as he wanted to go on tour with the piece. Again I recommended making a new Max patch that would enable this.

The clock tower in Hackney is the oldest building in Hackney. It has four floors and MA student Stephen Shiell and I agreed to set up two speakers on each floor. The clock engine frame is located on the third floor and there we set up the control room containing most of the equipment, including the mixer and the computer. The bell is located on the fourth floor and we also had two microphones on the roof.

I had three rehearsals with Stephen Shiell, Lou Barnell, Melaina Barnes, Hannah White and Phoebe Wright-Spinks, prepared clock, objects, electronics and field recordings. Stephen and I also had four meetings to work on coding and trying different Max patches. The penultimate day of the project was spent on a full technical dress rehearsal before the final public production on 29th April 2017.
From midday to midnight, the St. Augustine Tower was a dedicated performance space and live performance echoed through the tower and the surroundings.

[12] Audio available in the documentation part of this thesis, (Loren, Matt, Matt & Loren).

In the meeting with Sara, we discussed how Max may be used to pair gestural response with the manipulation of sound within a live performance. Sara was specifically interested in using motion-capture to affect the creation and playback of audio loops. I constructed several Max patches that explored the use of the in-built computer camera, live recording and playback functions in Max.

Her performance set out to investigate how it was possible to interact with the digital traces of our words once they are transmitted to the online world. Can our very presence and movement through this invisible forest affect the traces themselves?

She devised performance with a typewriter, using a contact microphone at the face of the letterpress to capture the sound of the typefaces punching the words. The captured sound was then augmented in Ableton before a motion-tracking patch in Max allowed us to manipulate the sounds heard by the audience through movement so that the audience heard the text but not in spoken form. The sounds they heard were affected by her movements in the space, a metaphor for how she interprets the use of text-based social media.

IV.b Research topics and major aspects of the work, Implementation

IV.b.1 Improvisation class 'The sensor box for the improvisation class'

I studied free improvisation during my undergraduate degree and in every session, I tried to perform with different instruments, analogue, digital and the combination of both, but eventually, my instrument became the computer and sound in general. For the student, I developed a sensor box as a controller for use in the free improvisation class, connected to different Max patches to control, generate and manipulate sound so that they could see the potential relevance the sensors and Max patch could have for their particular fields or projects.

Description of different type of sensors and the Max patch in the sensor box

Attached to the box were two different light sensors, a temperature sensor, a bend sensor, a pressure sensor, a knob sensor and a contact microphone attached to the box, which could be connected to an existing Max patch, allowing the students to control certain factors of sound such as frequency or pitch.

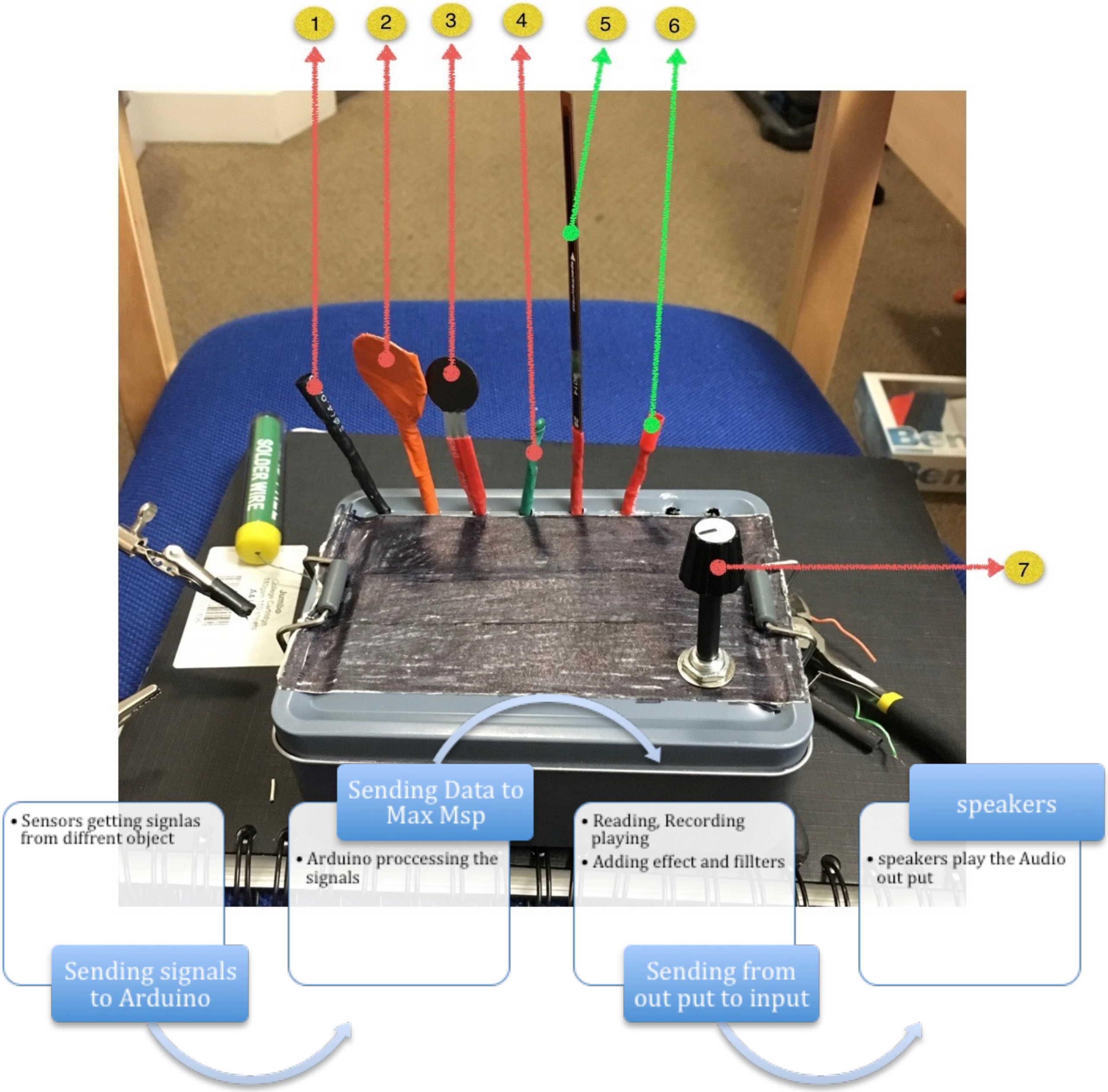
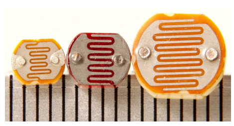


Figure 27. The sensor box for free improvisation class.

Figure Explanation

Figure 27.1 Light sensor, Light-dependent photoresists, LDR-MG45, 4 mm.

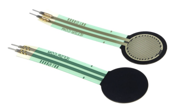


The data from this sensor manipulated the audio output of all frequency generators/synthesisers and was also scaled the data from 0 1 to 132 528 to manipulate the elements of Frequency Generator #4.

Figure 27.2 Piezo/Contact microphone.

This sensor connected and received data from the Arduino which is inside the box. The data were scaled from 0 1 to 100 600 to manipulate the elements of Frequency Generator #1. There was also a contact microphone that was connected to a jack socket attached to the box.

Figure 27.3 IEE Pressure sensor CP151 (FSR151AS) 10 g up to 10 kg (Ø) 16.7 mm.



The data of the pressure sensor was scaled from 0 1 to 0 127 to play different MIDI of a key slider inside the Max patch which was then connected to the Frequency Generator #1. Depending on the amount of pressure that students put on the sensor they could play and trigger different MIDI keys from 0 to 127.

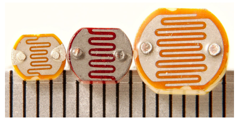
Figure 27.4 Temperature sensor, Etc 103 TTC 103 NTC Thermistor 10K Ohm.

The data of the temperature sensor was scaled from 0 1 to 132 528 to manipulate Frequency Generator #5. To activate this sensor students had to hold the sensor with their hands to use their body temperature. For health and safety reasons we were not allowed to experiment with other elements such as ice and fire which might also have been used to activate the sensor.

Figure 27.5 Bend/ Flex sensor 4.5", Spectra-symbol 5014-28.

The data received from the flex sensor was scaled from 0 1 to 132 528 to manipulate the elements of Frequency Generator #2.

Figure 27.6 Light sensor, Light-dependent photoresists, LDR-GL5516, 5mm.



A light sensor with different light intensity than the first one was used and by projecting the same amount of light on the different light sensors it was possible to get different amounts of data/numbers. The data was scaled from 0 1 to 132 528 to manipulate Frequency Generator #3.

Figure 27.7 Knob, B1M Linear Potentiometer, 15mm Shaft.

The knob controlled the delay of all four Frequency Generators.

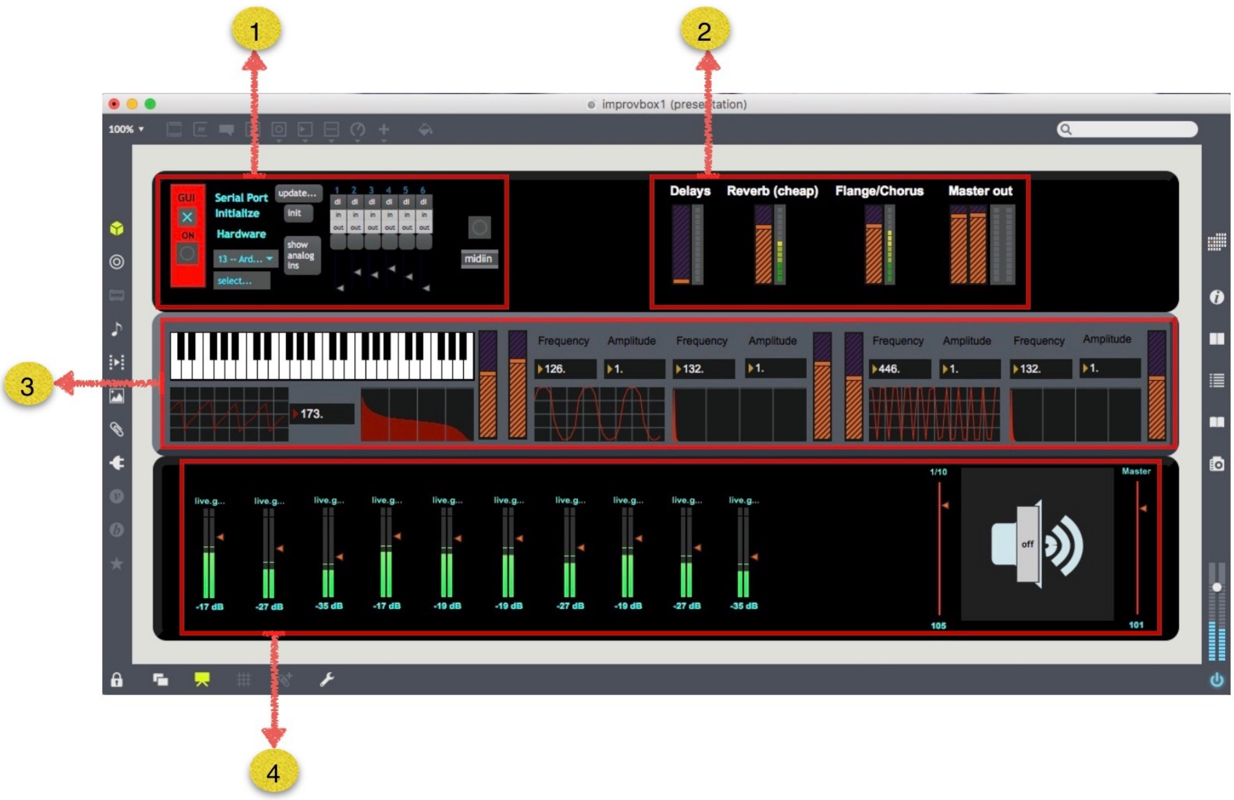


Figure 28. Final Max patch created for sensor box, (FREE IMPROVISATION).[13]

Figure Explanation

Figure 28.1 Arduino and sensor control centre /setting.

This part of the Max patch activated and deactivated the Arduino board and sensors within the Max patch to start receiving data from the sensors into the Max patch.

Figure 28.2 Delay, Reverb and Flanger/chorus effects and the master effects Output level.

These audio effects - delay, reverb and flanger/chorus - enable experiments with pitch and frequency by triggering the sensors.

[13] Final Max patch is available in the documentation part of this thesis, (Improvbox).

Figure 28.3 Playing around frequency/pitch.

By using different sensors students could manipulate pitch and frequency. Dr Jennifer Walshe and I agreed that all the sensors should be connected to these two parameters to keep everything simple so that the student could understand the basic of working with sensors.

Figure 28.4 Ten Outputs channels and Master output of the Max patch.

IV.b.2 Collaborative project with Matt London and Loré Lixenberg, the *Shard* patch.

Figure 29. *Shard* project set up.[14]

Initially, I modified Matt London's existing Max patch for *Shard,* replacing several objects inside the Max patch and adding a Korg nano pad 2 to replace the foot-switch. But I was not satisfied with this set-up so I mirrored the Max patch on an iPad wirelessly through Mira to monitor anything that happened during the performance;

If anything went wrong I could correct it behind the stage on the tablet.

For Matt's second performances and European tour I made a new Max patch from scratch and converted it to an application for him to use with a very cheap key switch-pedal which worked as a stand-alone. Everything could be set up for the performance by a few clicks in the Application.

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[14] Video available in the documentation part of this thesis, (Setup).

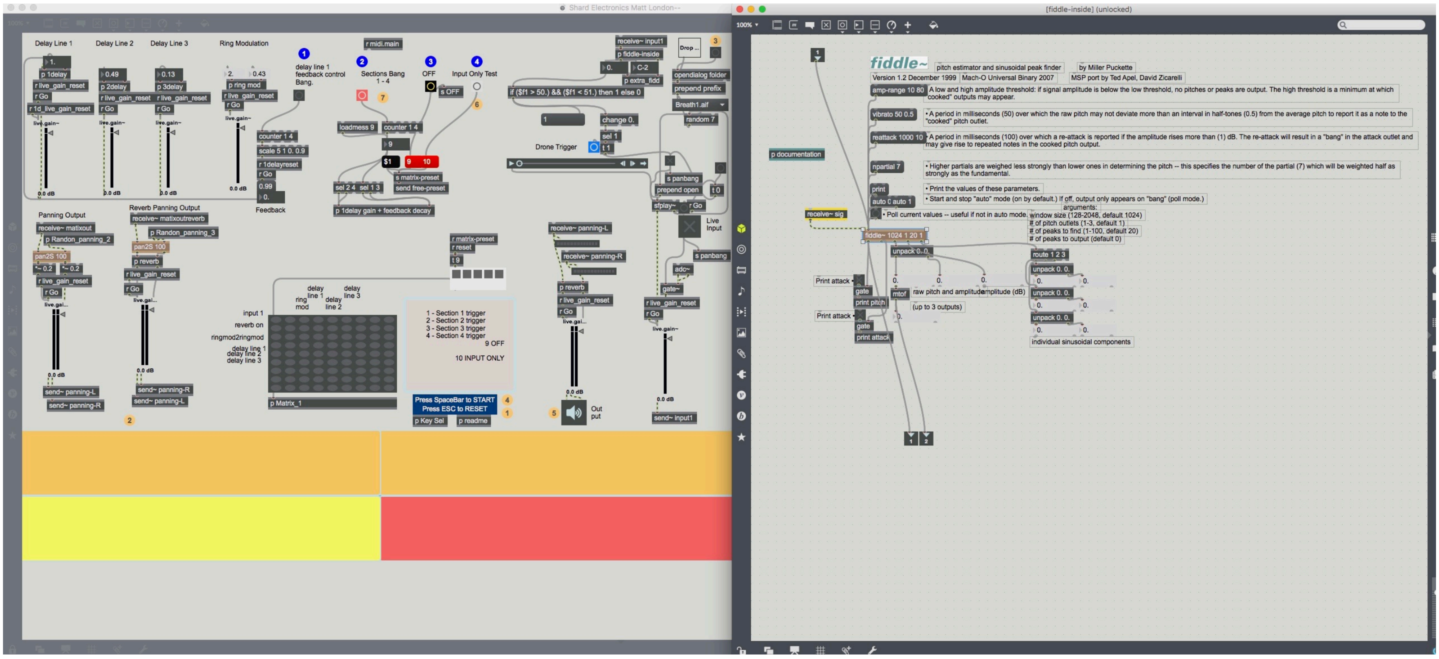

Figure 30. First Max patch for *Shard* (The previous Max patch).

Figure Explanation

The Max patch contains delay, reverb, timer and matrix to control the level of effects and the volume for each part of the piece. There were several problems with the previous Max patch: the fiddle~ object did not work with new updates of the Max programme and some parts were disconnected or missing within the audio and data connection. Matt also no longer had access to the effects switching pedal.

This figure shows the Max patch that Matt had been using previously. The right window of the figure shows the fiddle~ object that did not work any more. This had a key role in the piece: when the performer played a specific note, in this case, the E2[15], the Max patch would recognise it and activate pre-recorded tracks. The fiddle~ object needed to be replaced with an object inside the Max patch known as fzero~.

15 Audio available in the documentation part of this thesis, (E2).

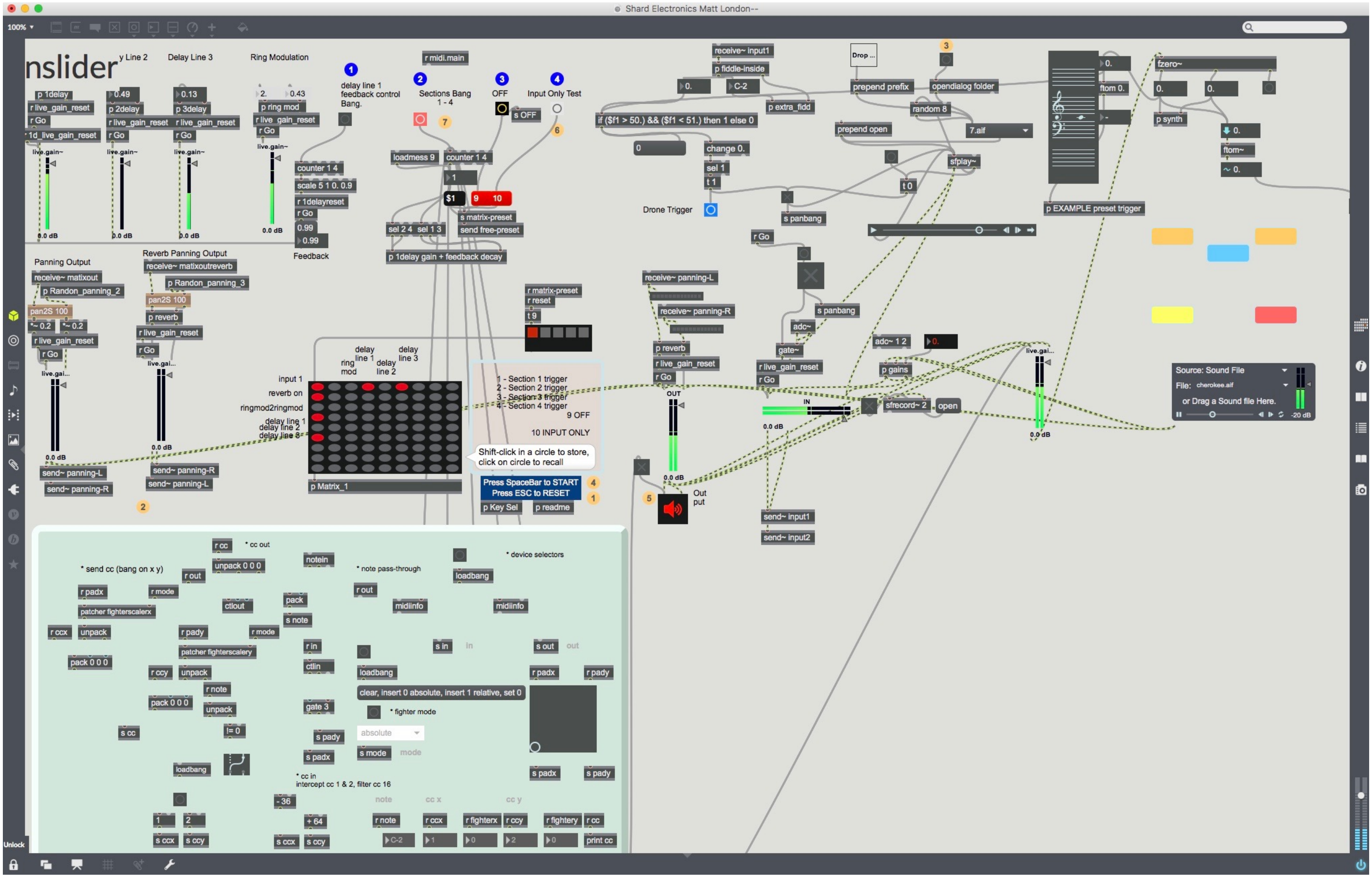

Figure 31. Fiddle~ object replaced by fzero~ object.

Figure Explanation

The fzero~ object works well for MIDI instruments and instruments which have a pitch very accurately such as electric guitar or piano. For this performance, the instrument was a baritone sax and the distance and the position of the bell of the sax to the microphone was very important. In this case, it was a normal condenser microphone, not the condenser clip-on microphone which is specifically designed for this instrument, so if the performer could not keep the right distance and angle between the microphone and the instrument then the triggering of any note for the Max patch would be difficult or impossible. In order to avoid these problems a tablet with Mira App was used to mirror everything that was happening in the Max patch from a distance so that, if the performer could not get anything to work within the Max patch at the right time, I would play the pre-recorded sound for him or switch between the effects.

The issue of the missing pedal, which needed to switch between several effects during the performance, was resolved by adding a nano pad 2 MIDI controller to the Max patch, so that Matt could switch between the effects like a multi-effect pedal for an electric guitar. Again, using a tablet I monitored the performance so that if the performer was unable to switch around using the nano pad, I would do it on the tablet.

Figure 32. The second Max patch presentation mode created for Matt London, *Shard* performance with Loré Lixenberg, mirroring on a tablet via Mira.

Figure Explanation

The left side of the image above shows the final presentation mode of the Max patch on the computer and on the right side is the mirroring of the Max patch via Mira on the tablet to monitor the activities of the performer during the performance. If the performer failed to press the pedal or any other factors of the Max patch then it would be possible to control the Max patch instead on the tablet.

The next version would be a new Max patch so that the performer does not need a CMD and can use it independently.

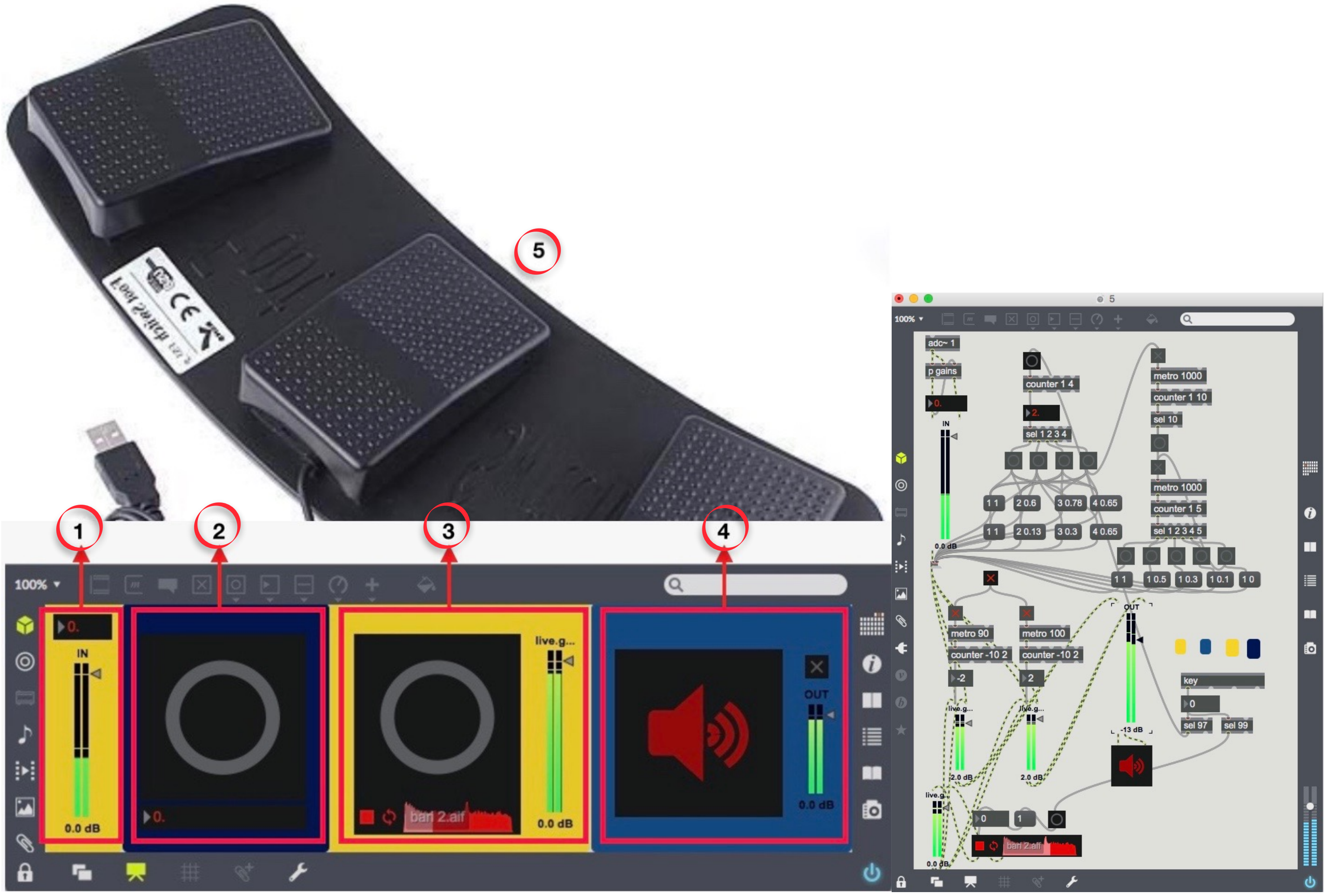

Figure 33. The final, completely new standalone version of the Max patch with a three foot-switch pedal, which was simple, user-friendly and inexpensive was specifically designed for the performer Matt London.[16]

Figure Explanation

Figure 33.1. The input volume, gain value and input channel amplitude fader.

Figure 33.2. The multi-effect foot-switch.

Select the right effect number for each different part of the piece by pressing the switch pedal.

Figure 33.3. The AIFF sample player and foot-switch controller.

Drag and drop sound sample and the Amplitude output fader.

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[16] Final Max patch and APP are available in the documentation part of this thesis, (Matt, MattAPP).

Figure 33.4. The DSP and output sound setting, master output fader, ON/OFF sound.

Figure 33.5. The three foot-switch USB pedal.

The next version was a new Max patch so that the performer can run the Max patch themselves. As a result, a three foot-switch USB pedal was used.

More information about the new Max patch for *Shard*:

A hint option was introduced, to help the performer to identify what each panel and object stands for by pointing at each with the cursor. This was also exported as a stand-alone application which enables the performer to use the application without having the Max programme installed on their computer.

The timing and algorithm bang for the delay, where to start, where to stop or after how many seconds turn off all effects or automatically change them to another level.

Out of three foot-pedals, two were used for the *Shard*. The first controlled four different effects, the fourth of which also had an extra option: by pressing the pedal, the Max patch automatically selected effect four and after ten seconds started to fade out all the effects gradually over five seconds.

The second pedal was used by the performer to play a prerecorded audio sample whenever the E2 note was played during the performance.

IV.b.3 Collaborative project, Hackney clock tower

The whole technical process of the clock tower project was very similar to the Chelsea Flower Show, using contact microphones attached to the frame of the clock or attached to the bell. Then the collected audio signals were sent to the Max patch. These audio signals were then manipulated by using several effects in order to use them for final audio production. All audio input channels were sent to the audio IN/OUT matrix part of the Max patch and from the matrix to the output channels and speakers. The matrix part of the Max patch could be controlled manually or randomly by having a time machine to set random audio in and out through the eight speakers which were placed within four floors.

In order to achieve the final outcome a MOTU interface was used, four contact microphones were attached on the clock frame[17], one contact microphone attached on the bell, two air microphone on the roof, four wireless air microphones for vocal, two passive speakers have placed for each floor overall eight speakers for four floors, a mixer and a Max patch which controls the effects, surrounded sound, timer and many other compositional factors for the piece.

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[17] Audio available in the documentation part of this thesis, (Audio).

Figure 34. Panoramic view of each floor of the Hackney Clock Tower Project.

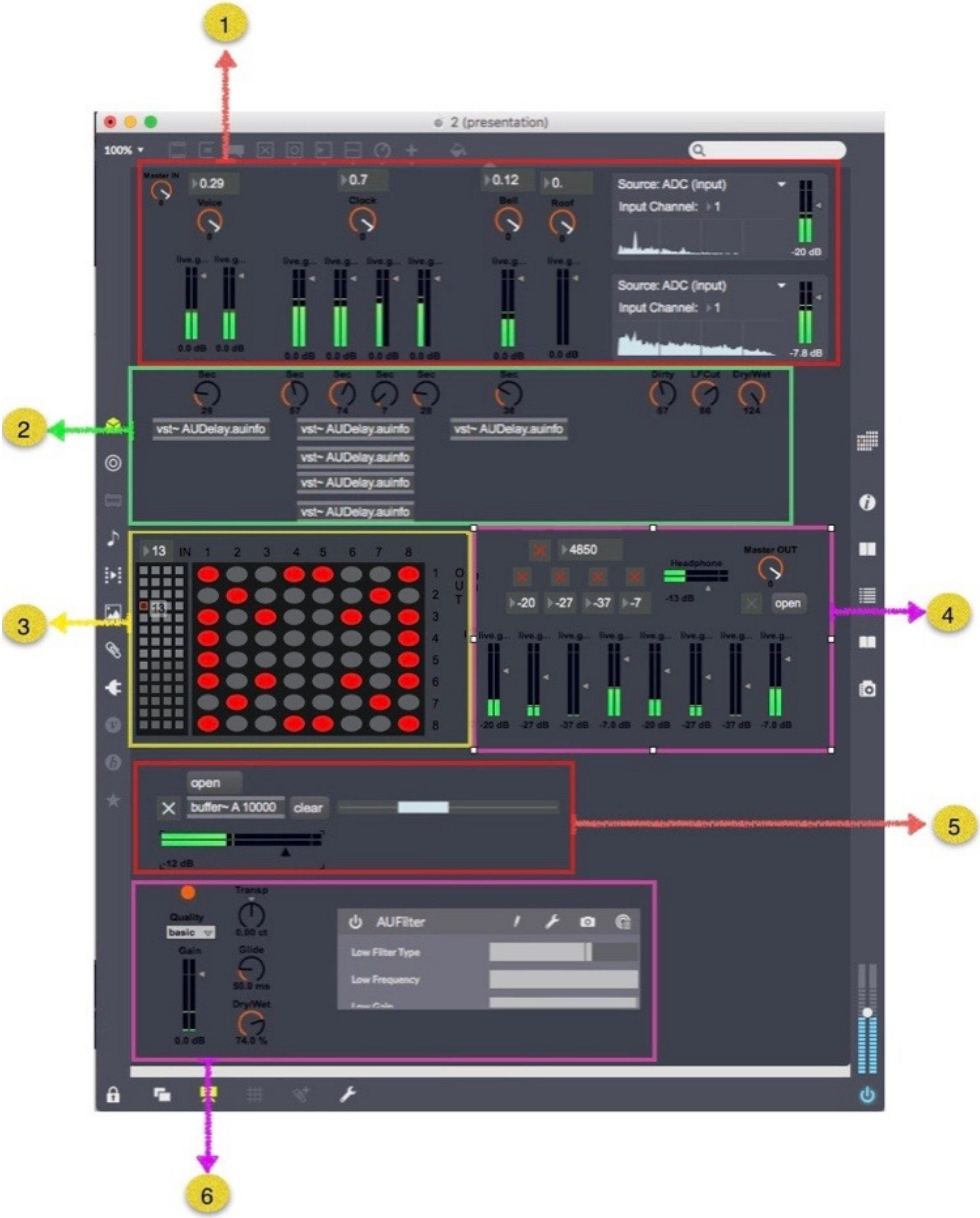

Figure 35. Final Max patch created for Hackney Clock Tower, Stephen Shiell.[18]

[18] The final patch is available in the documentation part of this thesis, (Hackney Clock Tower).

Figure explanation

Figure 35.1 Inputs channels and amplitude setting.

There were four contact microphones attached to the clock's frame and one contact microphone attached to the bell, as well as two air microphones on the roof and four microphones for vocals. All the audio inputs of the microphones are in this part of the Max patch. In addition, there were gain level controls, amplitude control knobs and faders for each audio input; all this can be controlled together by a master input knob.

Figure 35.2 All the effects and manipulating sound settings for all channels.

There was a delay effect for each audio input inside the Max patch and these delay effects have four different parameters for controlling the effects. The first parameter is the millisecond or timing of the delay which was separated for each audio channel by using a knob to manipulate each channel's effect independently. This parameter helps to create different rhythm/background pieces from the clock's sound sources, for instance, the frame, ticking and mechanical objects such as chains and cranks of the clock had been used during the rehearsing and performing for the composition of the piece. The other three effects parameter knobs were the dirty, low-frequency cut and dry/wet which were attached to three knobs with the same name to manipulate and play around with them, which then affected the same parameters for each channel's effects with the same level by rotating a knob.

Figure 35.3 Inputs and outputs channels' matrix plus the preset controller.

This part of the Max patch is the matrix and the presets in order to send eight inputs channels to eight outputs channels and it is also possible to send each audio input to a different number of outputs/speakers.

Figure 35.4 Outputs channels' amplitude, record, time machine/controller for outputs channels' amplitude level.

In this part of the Max patch it is possible to set a timer in order to change the matrix presets and also this timer can be manipulated in milliseconds. Another option in this part is to control the level of the audio outputs to speakers randomly or at a specific time. This part also included the headphone output, master output and all channels recording option.

Figure 35.5 Looper for all channels.

There were two different Max patches for looping so that performer could experiment with all the audio within the Max patch.

Figure 35.6 More audio effects for experimenting with sound and ideas for the compositional part of the project.

IV.b.4 Collaborative project with Sara Belle

Using a webcam on the computer to track colours, objects and Looping sound

Sara came with the idea of having a Max patch that contained colour tracking from the computer webcam. The data from the colour tracking of the Max patch would control different parameters of the second part of the Max patch: effects, on/off, loop and other elements. The camera tracked motion on the X/Y axis and the data were then scaled and selected by using the select and scale objects within the Max patch to control a pitch dial and recoding into the audio buffers. Left and right motion affected the audio recording and looping: up and down motion affected the pitch of the recorded sound. After further discussions it was possible to hone in on the functionality of the Max patch in the live performance environment, reducing some of the limitations of the prototype Max patches I had constructed for Sara. I created an improved colour tracking Max patch which was able to produce more accurate movement data allowing the performer to have a more responsive and comfortable performance environment.[19]

One of the best examples of colour and image tracking in the context of performance and dance is the camera tracking interface and software system EyeCon, designed by Frieder Weiss. His program captures the movement of performers on stage and then convert and use this information/data in order to trigger and play different audio samples, manipulated sounds or even musical chords, as well as images that were manipulated and projected on to the screen. The combination of the movement of the performance and sounds and images created a strong connection between what is seen and what is heard. (Steve Dixon 2007, p.201).

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[19] Video examples and Audio available in the documentation part of this thesis, (Video: A2, A3, A4, A5, A6, Sara1, Sara2),(Audio: Real and fake time 2).

Any movement of the performers' bodies was captured by the EyeCon and the data controlled the manipulation of the images which were projected on the screen. This data was also used to trigger and play different audio samples, manipulated sounds or even musical chords, creating a strong connection between visualisation and the sound of the performance. We had several meetings during the collaboration. I started with a small Max patch and then modified the Max patches together, as Sara wished to perform with one Max patch which then contained several Max patches doing different elements of the work together.

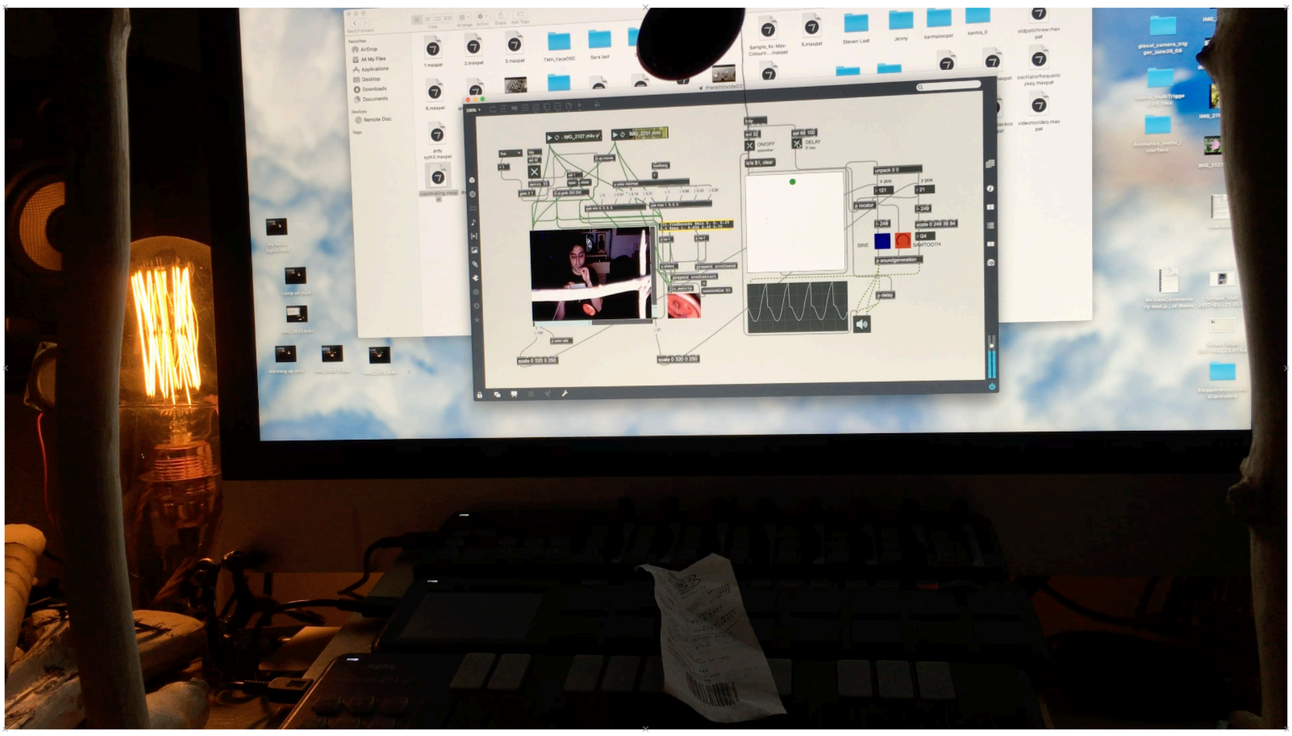

Figure 36. Image of a video example of colour tracking data controlling a Theremin inside Max patch. (The Video provided in the thesis material).[20]

[20] Video available in the documentation part of this thesis, (A1).

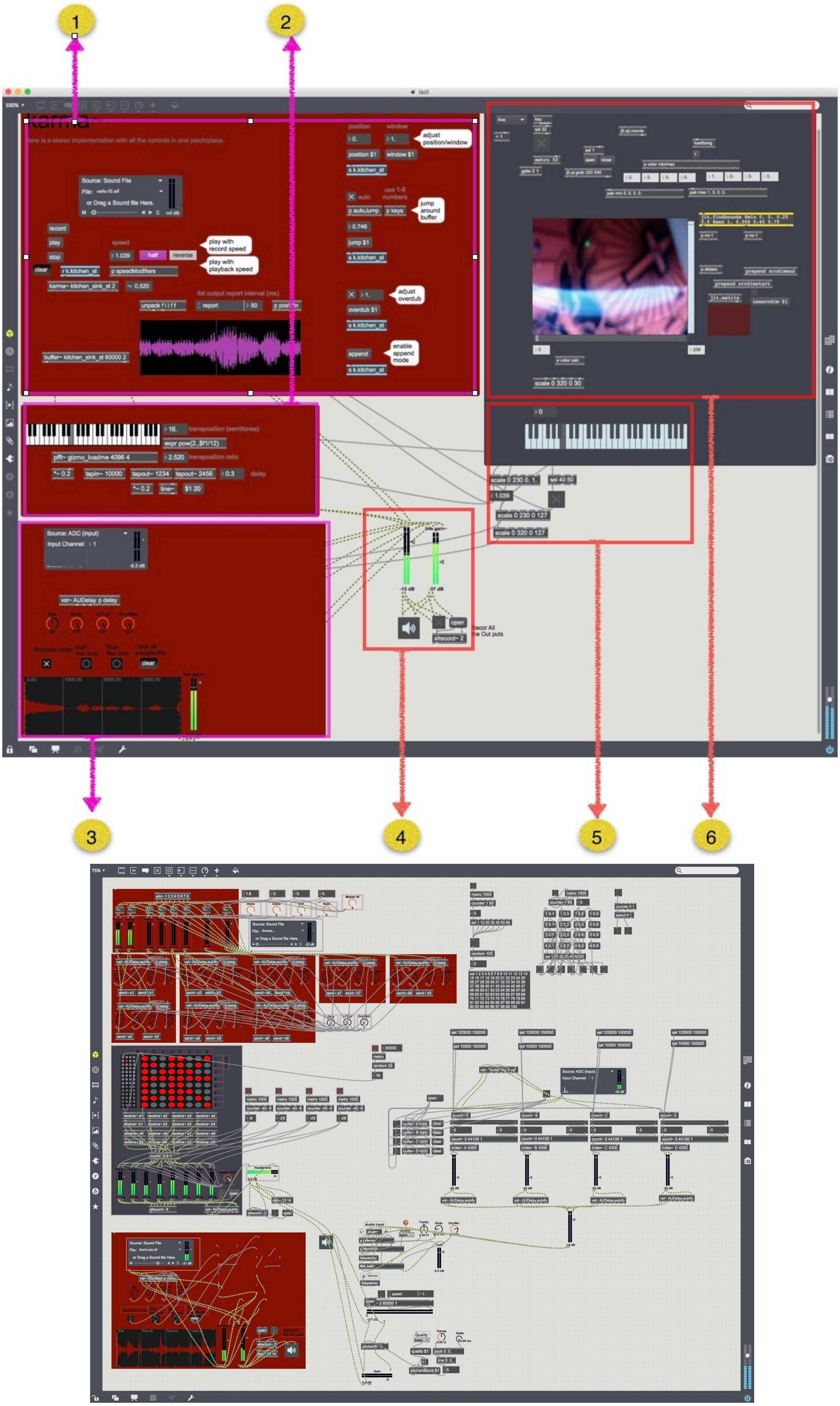

Figure 37. Several Max patches combined in one Max patch for Sara Belle.[21]

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[21] Max patches available in the documentation part of this thesis, (Sara1, Sara2).

Figure Explanation

Figure 37.1 Karma~ Looper Max patch.

Karma~ object is a looper/sampler external for Max by Rodrigo Constanzo. It is a dynamic length, varispeed looper with very complex features. It is possible to record, play, stop samples and modify the speed of playback and also reverse the window size of the samples so they could be changed. It is also possible to overdub with this object as required and to jump around the samples without clipping. The speed of jumping and where to jump in the buffer could be manipulated.

The functionality of the Karma~ object was controlled by a colour tracking Max patch, figure 40.5 and 40.6. An article with definitive colour would be placed in front of the camera and selected for tracking on the X and Y parameter. To start recording the colour object in front of the camera was positioned at the top left of the frame by the performer. To stop recording the performer moves the colour article to the top right of the frame. In working with Sara I showed her how to receive data from the camera and how to scale and select the incoming data from the camera in order to affect any objects, parts or buttons in the Karma~ Max patch.

Figure 37.2 Effect Gizmo object for karma~ patch.

This part of the Max patch added several effects parameters to the audio output of the Karma~ Looper and sent them to the audio output of the Max patch.

Figure 37.3 A looper Max patch and effect.

This is a looper that I made for Sara which contained a delay effect as an example for the performer.

Figure 37.4 Master out and sf-record~ object.

This part of the Max patch was monitoring the audio channel output so it was possible to record and save all output channels in AIFF format on the hard drive.

Figure 37.5 Scaling and selecting methods by using the scale and select objects for colour tracking data from the webcam.

Mapping input and output data in order to use for a different purpose.

Figure 37.6 Colour tracking Max patch (Mapping data).

This part of the Max patch uses the built-in camera or the USB webcam. By turning on the camera it was possible to select the colour of a specified article in front of the camera and track its motion. When the article was moved in front of the camera, by the performer, it was possible to get X and Y data value in the Max patch. This data was then scaled to control different parameters in the Karma~ Max patch so that the performer could control the function of the Max patch with motion.

IV.c Conclusions

In relation to the research questions

1. What were the limitations of this project?

2. What were the instruments comprised of that were developed as part of these projects?

3. What impact did the specific context of this collaboration have on the development of the instruments/installations, how was technology adapted to enhance performance?

4. What were the limitations and challenges presented by these collaborations and what other possibilities were opened up for the future?

IV.c.1 Pedagogical function and learning through collaborating with music students and working with sensors

The pedagogical function of the projects with music students mostly involved introducing different types of sensors and showing the students how they can interact with them through different programs. For these projects, my supervisors and I decided to make a basic introduction to different types of sensors, such as the sensor box for the free improvisation class. In other projects, the performers needed more specific technologies such as a pedal for Matt London's *Shard*, or a webcam for Sara's project to control and manipulate different parameters inside the Max patches, or for the clock tower project with Stephen where piezoelectric microphones/contact microphones were attached to the frame of the clock and the bell. All these projects involved a considerable amount of hardware with many hours of software programming, experimenting and exploring compositional techniques.

IV.c.2 Sensor box and free improvisation

An important aspect of using sensors is that it is possible to have full control of the incoming data in the Max patch, scaling, converting or mapping the data in any way necessary. These data can be connected and related to many other programs, objects, movement or other factors.

Using smartphones or tablet applications such as Touch OSC or Mira to control the Max patch can achieve much, but the sensors were able to expand and shape the performance in different ways. For example, a piece can be implemented just by lighting a candle and by using light and temperature sensors to control the Max patch.

This project allowed the development of a unique interactive instrument without the usual constraints of collaboration.

In the second class, the students made use of the sensors and Max patch in order to see the potential relevance they could have with their particular fields or projects.

When students first experimented with the sensor box, they were not familiar with how it worked: for example, which sensor was connected to which object or element inside the Max patch to generate sound, and how to use them. I advised them to slow down their movement to trigger the sensors. If they were triggering the flex sensor, attached to the Max patch designed to bend the flex sensor smoothly, bending the sensor smoothly would keep the frequency number steady in order to generate sound and the pitch they wanted.

After a while, they understood how the setup worked and they started to communicate, experimented by activating the sensors and listen to one another's sounds. By the end, there was a strong connection between the improvisers and the sound they generated.

Sara Belle

Using this custom Max patch, Sara was able to create several recordings. My collaboration with Sara allowed her to explore the basic use of the Max patches and explore her ideas more thoroughly.

Matt London

Making the Max patch as simple as possible and using presentation mode to hide the complicated processes in the main Max patch enabled a certain degree of plug-and-play operability for the performer.

Conclusion

Conclusion Questions

1. What are the CMD's role and limitations when collaborating?

2. Does collaborative creation facilitate innovation in the design of interactive instruments and new work?

3. What are the limits and restrictions of collaborative work in terms of innovation in music technology and sound design?

4. What is the importance of Max and similar programs in the collaborative process?

5. How might the CMD enhance performance/composition through the development of interactive instruments?

Role of CMD in collaboration

There is still a lack of recognition and understanding of the many roles of a CMD, in part because of a lack of transparency in computer music creation, and also because of the traditional prestige associated with the role of the solo creator. This misunderstanding and the general wariness about the act of collaboration, combined with the reticence around new forms of musical expression, are still problematic hindrances in the development of the role. As Zattra observes:

> The naming of the assistant's occupation followed a tangled path, reflecting the emergence of this career (Zattra 2013). During the 1970s, names such as scientist, researcher, engineer and technician were used equally. The designations of tutor and musical assistant emerged during the 1980s. Finally in 2007, to achieve a more effective and stable appellation, the title Réalisateur en Informatique Musicale (RIM) was chosen, which is usually translated as computer music designer. (Zattra 2013, p.118).

This thesis is intended to contribute to the literature that documents, explores and demystifies this role.

Figure 38. Pierre Boulez at a desk working on Répons at IRCAM, 1984 (IRCAM, Paris, Espace de projection). Seated left to right, Denis Lorrain, Andrew Gerzso, Pierre Boulez; standing, left to right, Emmanuel Favreau and Giuseppe Di Giugno; sitting in the back of the room, unknown. Source: Courtesy ©Marion Kalter.

This thesis has focused on the technical and practical aspects of the role and activities of the CMD in collaborations and less on the philosophy or concept behind any individual work. My role as CMD in each of these successful and varied projects will, it is hoped, provide a resource of useful examples in studying this new role.

The social aspect

It is important to understand one's partner in any collaboration, their age, experience, mindset, ambitions, etc. when performers or composers are not clear about what they want or need, or do not know what is possible, the role of the CMD is to provide possible solutions. While this differs from project to project (many rejected suggestions or fewer more targeted suggestions) the role of the CMD becomes something of a tutor or teacher before taking on the technology of the project. As a CMD, I have had to familiarise myself with the technologies that performers have used for a long time (e.g. foot pedals as triggers), even if I feel there are better alternatives.

While I have not focused on the psychology and more intricate social aspects of the role of the CMD, relational parameters are important in collaboration. One such explanation of overcoming inhibitions might be found in the way a project will advance through some form of serendipity as different solutions are explored. In *Synchronicity* Carl Gustav Jung tells this story:

> My example concerns a young woman patient who, in spite of efforts made on both sides, proved to be psychologically inaccessible. After several fruitless attempts to sweeten her rationalism with a somewhat more human understanding, I had to confine myself to the hope that something unexpected and irrational would turn up, something that would burst the intellectual retort into which she had sealed herself. Well, I was sitting opposite her one day, with my back to the window, listening to her flow of rhetoric. She had an impressive dream the night before, in which someone had given her a golden scarab, a costly piece of jewellery. While she was still telling me this dream, I heard something behind me gently tapping on the window. I turned around and saw that it was a fairly large flying insect that was knocking against the window-pane from outside in the obvious effort to get into the dark room. This seemed to me very strange. I opened the window immediately and caught the insect in the air as it flew in. It was a scarabaeid beetle, or common rose-chafer (*Cetonia aurata*), whose gold-green colour most nearly resembles that of a golden scarab. I handed the beetle to my patient with the words, "Here is your scarab." This experience punctured the desired hole in her rationalism and broke the ice of her intellectual resistance. The treatment could now be continued with satisfactory results. (Jung & Campbell, 1971, p.511,512).

Sometimes I have proposed creative solutions that have the potential to add an extra element to a work, but these suggestions are rejected either for practical reasons, reticence towards innovation or in some rare cases because my role has not been understood to include the creative as well as the technical. As a consequence, the final project does not always reflect the work and innovation that went into its making.

There are many possible configurations of a collaborative project. Finding the balance of power, ambition, direction and organisation is part of the process. According to Sennett in 2012, the spectrum of the give and take exchange can be defined as follows:

1. Altruistic exchange, which entails self-sacrifice.
2. Win-win exchange, both parties are equal and benefit from the cooperation.
3. Differentiating exchange, parties are aware of their respective differences.
4. Zero-sum exchange, one party prevails.
5. Winner-takes-all exchange, one party completely defeats and wipes out the other). (Sallis et al., 2018. p. 74).

Collaboration is different in different art forms: the collaborative work with MA Drama students was more complicated and in many ways, different from what normally happens during a project with music students. Physicality and space are more important in theatre so I had to find ways to integrate the technology into the concept of the piece itself and this involves some form of staging. The equipment needs to be hidden. I also needed to provide multiple solutions to trigger a sound: using a pressure sensor, a light sensor and many other gestures are all options, but the skill of the CMD is using the one that works the best for the situation.

Finally, the CMD might have to deal with a performer who is anxious and stressed about using unfamiliar technology and having to perform with it. It is important to make them feel comfortable by talking to them, monitoring everything that is happening during the performance and, in case anything goes wrong, having techniques to deal with the problem.

Techniques and working with sensors and challenges of CMD

No matter how complicated a program is, it must be simple for the user to operate the interface. The user needs to be comfortable with the program so that they can operate the program without necessarily having any idea about music programs or programming in general. In the collaborative projects in this thesis, I have also used elements such as drag and drop audio files or having the hint option for each object in the final application so that the user can see the function of each part of the application.

I exclusively used Max for these projects because although it is complicated, it is both accessible and affordable and other programs are limited or very complicated. Max can be a very helpful environment for the user to imagine and connect in logical, random or any combination of sound or data: it is also a blank page on which users can draw whatever they wish.

It is important in designing any patch that the graphical design of the interface enables the user to view and interact with the patch, showing where objects are placed inside a patch and using colour coding to enable the user to quickly access different parts of a patch. The approach is very close to that of a Luthier who makes a bespoke instrument for each performer (or collaboration).

The topics in this conclusion — the role of CMD in collaboration, the social aspect and the techniques and working with sensors and challenges of CMD — are all important in any project and they are all interrelated. As a CMD, it is important to keep the balance between these topics. This leads to another important aspect of the role the CMD is often required to have: project manager. The complications and problems might be technical, psychological, social or logistical, but the CMD is required to master all these activities.

Great creators are not unknown for being eccentric. Artist Salvador Dali commented that he owes his success to ‘ Slumber with a key.’ This was his afternoon nap which he took with a twist. To do so, he slept in a chair while holding a key. He would sleep and allow the key to fall to the floor. The clang of the key would wake him up. Consequently, little sleep periods like these were the ‘keys’ to his success. He learned this trick from Capuchin monks. (L, 2018).

Each individual person needs to find their own ways to be innovative and the personality of the creator will emerge if the right tools are being used. The work of the CMD is to find, modify, or create those tools.

Appendices

A. Chelsea flower show documents

This email from Dame Evelyn Glennie was selected to show an example of the teamwork between the Brunel University London team and Dame Evelyn Glennie.

Ardeshir and I had a great afternoon today on site exploring the sounds of the garden and their sonically manipulated other versions. Together with all the recorded sounds from your own percussion from the previous session with the students, I think there is a huge range of possibilities for what we can put together tomorrow. 'Subtle and wild' is certainly the way to go. The combination of being able to share what we have and being guided by your ideas about, for a musical backbone will I'm sure, be a winning combination.

It is important that all the sounds we have recorded are used specifically for the sound garden projects or anything related to that. Even if the sounds are transferred to actual pieces of music I feel it should always be acknowledged as regards to where the sounds originated from. We want to keep the whole ethos of the project and the strong Papworth message of 'Together We Can' alive.

I'm happy for the students to create more structured pieces for me to play live to without my sounds being enhanced. This will certainly simplify matters.

I've now had a chance to listen to all of the initial ideas you sent. The material works well with just the right amount of balance between real and enhanced/ manipulated. We have always to allow our spectators to believe in the sounds and that they have all grown from the garden itself. That will be particularly important to bear in mind on the days when I am not present.

The examples you sent along with anything else you work on would all be appropriate to use for the times I am not present at the show. Gauging when the sounds can be more sparse or busy is something that you can be aware of depending on the weather, how many people are present and the sound level the spectators produce, neighbours and so on. For example, you may wish to start each day with something more gentle and subtle but perhaps at lunchtime have something more busy and energetic. Being aware of the types of sound examples you use is also important - perhaps bells/gongs followed by drier sounds followed by deeper sounds followed by higher sounds and so on. We want to avoid having a morning of only gongs in water, for example!

It would be really useful for me to have the following loops:

Two rhythmic loops on water drums - one at a medium tempo and another much faster

One rhythmic loop from the individual sticks example at a fast tempo

Two rhythmic loops from any of the sticks on water recordings we did again at medium and faster tempos.

One rhythmic loop using only the marimba arms (ideally all of them).

Achieving a good balance between the rhythmic loops and the abstract material (for which we have a lot of) would be essential so that we have plenty of variety for me to play along to.

My main areas and ideas of performance will be (for the Monday and Saturday):

FLOWER POTS SUSPENDED - the suspended ones from the rack. These would be used in an abstract way so feel free to manipulate my sound as I play along with any of the pre-recorded flower pot material.

FLOWER POTS GROUND - the ones positioned on the ground underneath the suspended flowerpots. I would like to play segments of a piece called 'To the Earth' by Frederic Rzewski which employs my playing the pots whilst reciting. This could be done completely by itself without any background pre-recorded material.

WATER DRUMS ALONE- these would be used whereby I play them without any pre-recorded backing.

WATER DRUMS WITH BACKING - these would be played with a pre-recorded rhythmic loop. The loop would keep going for as long as I keep playing.

BLOSSOM BELLS/GONGS - these would always be played with abstract pre-recorded material. Therefore, we can have 3 abstract ideas that I can deal with. Bear in mind that I could start playing alone and very subtly you begin adding pre-recorded material. Your freedom in doing this is important - I certainly don't want to stipulate that in 30 seconds this or that will happen because most of what we shall do will be highly spontaneous and free.

WIND CHIMES - I would like the option of going to one of the designated areas where there is a microphone (possibly flowerpot area) and play the chimes alone followed by the pre-recorded material coming in as I play. The examples you gave in your email were really good. Getting the balance between that and my live playing will be important considering the chimes are so delicate. Again, manipulating my live playing is fine.

WATER PLAYING -she was playing with the water by using different sticks, mallets, tools to beat and create rhythm from the water.

GRAVEL - Using the gravel and other natural 'small' sources in a very subtle way would work were some of the pre-recorded material we used of the same idea in order to make it interesting.

BALAFON (African Xylophone)/LOG DRUMS - was played with the marimba arms. Adding effects on to the arms add effects on them whilst she was playing.

In between the performance pre-recorded material was added to the whole performance at different time.

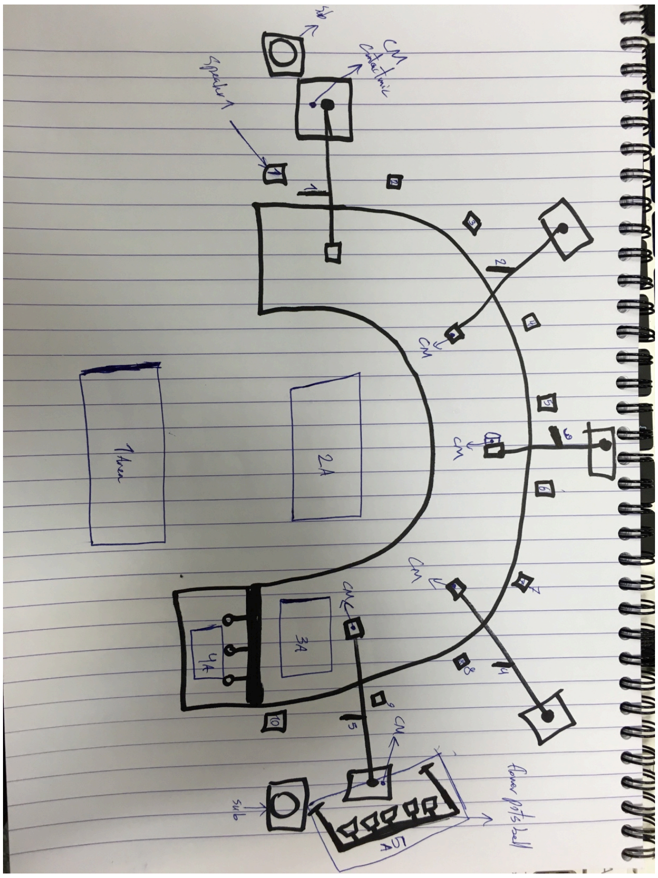
It would have more or less the instruments I had available when we did the recording. They would all be positioned in a way that would accommodate the agreed microphone areas. However, I shall go with Peter's advice as regards to what aesthetically works with the garden as a whole.

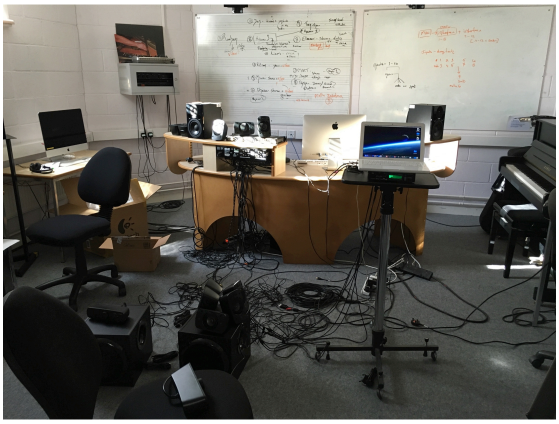
You can type up the above information however you wish so that you have it at hand during the show.

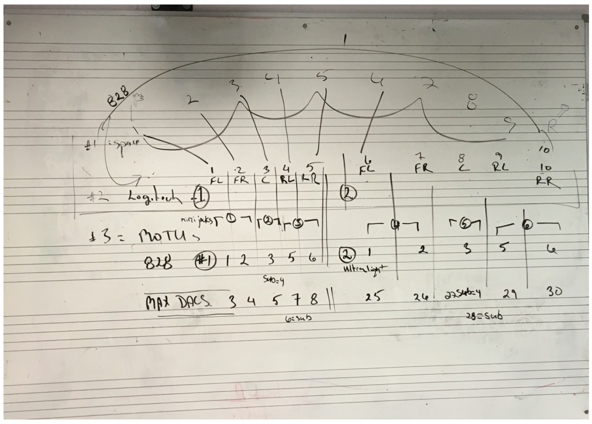
Meanwhile, I'm looking forward to experiencing your further musical ideas. Nothing needs to be set in stone but at least the above gives us a positional and sound structure as regards to what I would do.

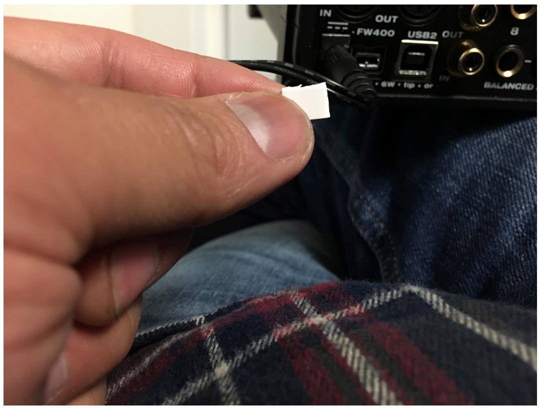
The last point I would remind ourselves of is that we try to think of happy soundscapes as well as those which are more contemplative. It's easy for the abstract ones to be darker in mood. I'm thinking about the garden itself and Peter's comment about the daisies, for example, being happy flowers, singing to us, as though they're choir boys with ruffled necklines. Textures in the sounds will be so important just as it is in the make-up of the garden itself.

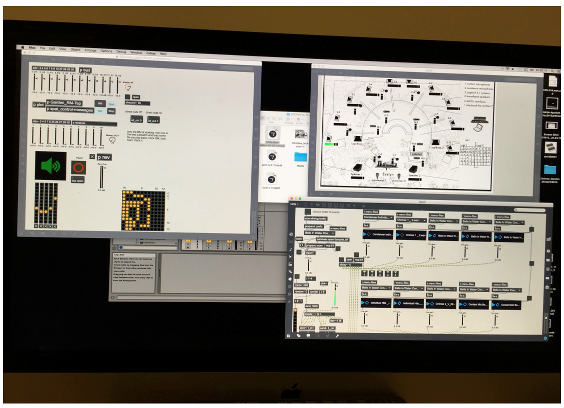
Figure 39. Twenty-seven images from the beginning to the end of the Chelsea Flower Show project.

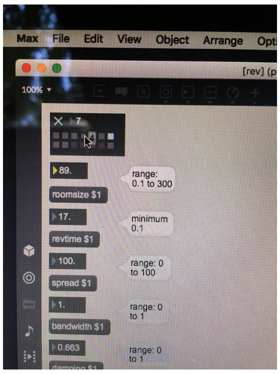




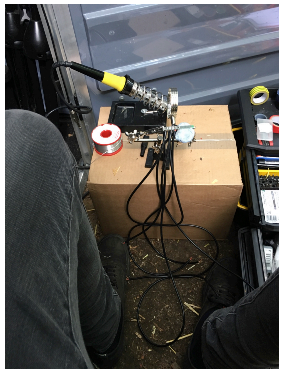

828
Logitech
MOTU
MAX DACS


IN
OUT
FW400
USB2
BALANCED



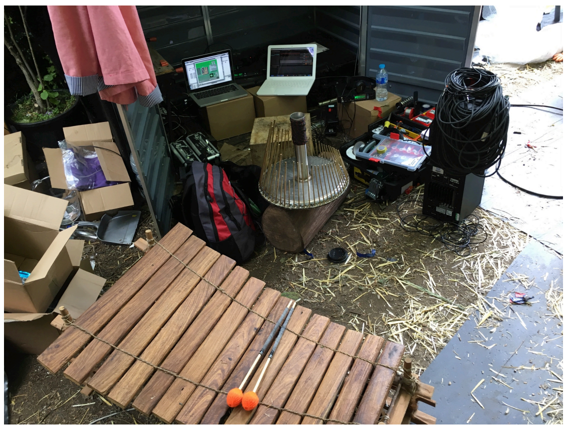

Max File Edit View Object Arrange Opt
[rev] (p
100%
89.
roomsize $1
range: 0.1 to 300
17.
revtime $1
minimum 0.1
100.
spread $1
range: 0 to 100
1.
bandwidth $1
range: 0 to 1
0.663
range: 0 to 1









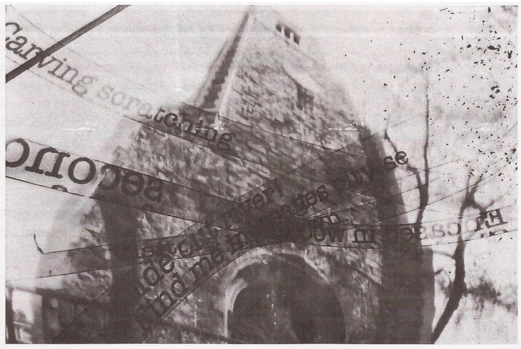





B. Hackney clock tower documents

How do you capture a moment of sound in time? How do you photograph a voice? E5 Process photography collective have been collaborating to explore how collodion process and pin-hole techniques can be used to capture fragments of time at the tower.

TIME: A SONIC VIGIL
BY BREATHING SPACE
With E5 Process collective



Now when our bits of selves gather in the tower
With machines to filter scattered drones
Our voices repeat the ticking hours
We sing in time, in sound, in stone

#SONICVIGIL

This piece marks the end of a six month residency at the tower. It began as a place for us to spend time experimenting, reflecting on our site-specific practice, exploring resonance, and using sound to contemplate the building materially, historically and socially. As the months went by we became increasingly focused on Time as a central theme to the work; as a construct and a natural force, how we value and perceive it in our work and daily lives, its contradictory nature as both regimented and elastic, and its fleeting, strange and unyielding qualities. We amplified the clock and experimented with delay and repetition, layering vocal harmony, dissonance, microtones, rhythmic patterns and loops, and using the resonant frequencies of each floor to create drone layers, allowing the whole tower to became a performative body, with a central heartbeat and sonic limbs extending into the surroundings.

The collaboration with E5 Process collective began with a desire to leave behind a trace of performance, a relic or document. Their practice uses time-bound traditional processes of collodion and pin-hole photography creating a visual parallel to the performance, experimenting with timed exposures, light play in the tower and developing loops, techniques to capture fragments of time, lengths of sound, movements in space.

Today is a way of marking our time spent here. You will experience fragments as you move through the tower. We ask that all phones are turned off, or on flight mode. This is to encourage a fresh state of mind, an 'in the moment' experience, a disconnection from the world and a slip into strange time as you spiral through the tower, whilst also preventing signal interference with sensitive radio mics.

When you enter the tower you are entering a performance space, please only talk when necessary and participate by being present.

BREATHING SPACE:
Lou Barnell
Melaina Barnes
Stephen Shiell
Hannah White
Phoebe Wright-Spinks

SOUND DESIGN:
Ian Thompson

SOUND ENGINEER:
Andy Nuttall

TECHNICAL SUPPORT:
Ardeshir Mostajeran

IMAGERY:
E5 Process Collective

PARTICIPATION

Access to the roof is an experience for one person at a time as it is a performance space.

This does not mean you have to perform if you go up, but there is a microphone on the roof that is picking up the sounds of the surroundings and feeding these into the tower. This gives you an opportunity to participate in the piece. You are invited to speak about Time and your personal experience of it, or read one of the pieces of text provided. Your voice will be amplified into the tower.

If you need some inspiration you could think about Time in response to the following questions:

Does a minute always feel like a minute? Is your time the same as my time?
What is the worth of your time? What is history? How do you spend time wisely?

If you'd like to go up to the roof, to participate or just to enjoy the view, tell the steward on the third floor in the Bell room, they will be operating a one-up one-down system so you may need to wait a few minutes.

CREDITS

WE WOULD LIKE TO THANK:
Vic, Jo and Tim at OCM for believing in us and supporting us throughout the year
Doug, Guy and Tina from E5 Process collective for their creativity and commitment to the project
Hackney Historic Buildings Trust for giving us a key to the tower
Department of Creative Professions & Digital Arts at Greenwich University for supplying sound equipment
Sonic Meditation Study Group for participating
All the volunteers for giving us their time

This project was funded by Oxford Contemporary Music's BOOM 2016 program, which offers support for practitioners interested in creating and presenting inspiring contemporary music or sound based work outside of the concert hall and gallery. The programme is supported using public funding by Arts Council England and supported by PRS for Music Foundation.
www.ocmevents.org/boom

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@E5Process

Oxford Contemporary Music — University of Greenwich — creative professions digital arts — Supported using public funding by Arts Council England — PRS for Music Foundation

The piece is the culmination of a six months residency at the tower supported by OCM's BOOM program and I supported by Hackney Historic Buildings Trust and the Department of Creative Professionals & Digital Arts at Greenwich University.

St Augustine's Tower is a four storey church tower and this performance is spread across all four floors and the roof. The stairwell is a narrow, spiral stairwell. There is very limited disabled access to the building.

From midday to midnight St Augustine's Tower will be a performance space dedicated to the exploration of Time; as a construct and a natural force, how it is valued and perceived, regimented and elastic, strange and unyielding. Sounds from the clock, the surroundings and live performances will echo through the tower, merging and reforming, shifting and resting, sonic ghosts appearing and disappearing across the twelve hours like sand through an hourglass.

«So, when its spiral spine and cladding stones appeared
The old selves who roamed freely through this land
Felt their hope get ground with types of fear
As light was slowly taken and space darkened
Now when our bits of selves gather in the tower
With machines to filter scattered drones
Our voices repeat the ticking hours
We sing in time, in sound, in stone
Images vanish and reappear
Material records of stolen light
And the tower keeps on standing here
As we plant wild noises to celebrate
So when the darkness falls again
The old selves soar in sound, in sight»

C. Matt London's *Shard* documents

for Marij van Gorkom

Shard

Amplified Bass Clarinet & Electronics

Composer: Matt London
Electronics: Benjamin Fox

Shard

Amplified Baritone Saxophone & Electronics

Composer: Matt London
Sound design: Ardeshir Mostajeran

Glass
Beautiful, translucent and clear
Reflection
The unforeseen tension
Hard, brittle, cutting
Refraction

This piece looks at sound as if it where light passing through glass constantly shifting and shimmering. Sometimes corse and sharp imagine a visceral energy like an electrical undercurrent passing through unseen before it breaks and shatters.

ML | November 2017

Performance note:

The work is broken down into three sections; opening text page, **B** and **C**. Each has a different Max MSP set up within the patch relating to the differing treatment of sound and spirit of the composed music. The score is openly notated for you to make your own… if you want to expand and depart from the written notes you can!

Each setting is triggered by the performer using a foot-switch. These switch events are marked on the score by an **S** for switch and a corresponding switch setting number.

Opening text page - [S1 and S2] S1 is triggered and the player builds an atmospheric texture by layering various non full tone sounding extended techniques leading to a multiphonic (31) crescendo. S2 is then triggered by the player for section **B**. Remember to take your time in building up the texture.

B The build up of energy - [(S2), S3, S4] An exploration of tone colouration. The hidden undercurrent of energy becomes more apparent as this section develops. S3 triggers a loop-like event for the player to build an unrelenting wall of sound. On your final repeat trigger S4. S4 triggers a 5 second fade out → move onto line 18 the wild harmonic gliss. An automatic transition to S5 means no switch is needed for this (S5).

C Reflection and dissipation - [S5] S5 is already on! No trigger needed for performance. S5 produces a drone that comes out of, and continues when a low E (transposed) is played. This last section reflects upon the previous material. It explores a more subtle refraction of fading light before it finally sets. Remember to take more time and space with this section, especially stretching it out from line 27 to the end.

Performance techniques information

Slap tongue:
Three types of slap tongue are intended to be used: 1. Reverse slap 2. Slap tone 3.Thwack
All three will be represented with a " x " notehead.
1. Reverse slap - Soft melodic
2. Slap tone - Closed
3. Thwack - Percussive thwack (ram)

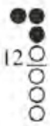
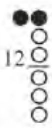
Multiphonics:
All multiphonics are notated plus a finger chart. Suggestions on how to trill or bisbigliando are added to the chart.

Harmonics:
" o " will be placed above the notehead.
P = partial (harmonic series)

Bisbigliando:
Fingering options for bisbigliando are open for the player to decide on. However optional suggestions may be given at certain times.

Velato: (veiled)
An improvisatory device play indistinctly quickly with a half open sound to create an eerie sound.

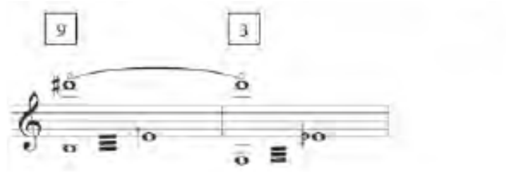
Multiphonics list:

Proposed fingering	Sounding result	Proposed notation	Stability	Tonguing	Dynamics	Embouchure	Other remaining remarks
05 			1	2	*p* → *f*		Bisbigliando with key 8
09 			2 - 3	4	*mf*		Needs a lot of air. Bisbigliando with key 5
17 			4	4	*mf*		4th finger of the right hand is also playing key 9
27 			2	4	*pp*		Normal fingering, only embouchure change
28 			2	3	*p* → *mf*		Bisbigliando with the 3rd finger of the right hand. Trill with key 10
31 			1	3	*p* → *ff*		Trill with MF30 and key 10
37 			1	2	*p* → *mf*		Trill with MF36, MF39 and key 15
39 			2	2	*p* → *f*		Trill with MF37. Bisbigliando with key 15

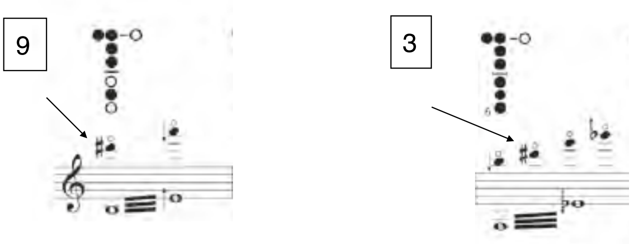
Proposed fingering	Sounding result	Proposed notation	Stability	Tonguing	Dynamics	Embouchure	Other remaining remarks
41 10			1	3	*mp* → *f*		Needs a lot of air
54 14			4	3	*mp*		Quite unstable
55 14			2	3	*mp* → *mf*		Same fingering as MF54, only change of embouchure. G♯3 sometimes very clearly audible
56 10 14			1	2	*mp* → *mf*		Bisbigliando with key 14.
57 10 14			4	4	*pp*		Same fingering as MF56, only change of embouchure. Very unstable!
70 18 7			2	3	*mp* → *f*		Bisbigliando with key 7
71 18 16 14 (6)			2	2	*p* → *mf*		Trill with key 14
79 16 7			1	1	*pp* → *ff*		Trill with MF78 (key7). Bisbigliando with 2nd finger of the right hand. Very stable
89			2	2	*p* → *mf*		Normal fingering, only embouchure. Combination with MF6

Tremolo with fixed overtone - line 22 (score)

score example:



This effect is realised by playing a trill with the index finger of the left hand. The high overtone desired is D# (transposed). For box 9 this is the first partial, for box 3 this is the second partial.



Tremolo with overtones - line 24 (score)

Slightly increase the lip pressure and move the lower lip millimetre by millimetre to the base of the reed, the following harmonics will appear.

Technical equipment set up:

The following is an equipment list used by MVG for the performance of Shard. It is intended as a base guide for other performers who may have differing set ups.

function	type	notes
computer	Macbook Pro	2,7GHz dual core / 8GB RAM, 13-inch
software	Max 6 [a]	please make sure your patch works in the latest version of Max [b]
audio interface	RME Fireface UCX	sampling rate: 44.1 kHz input 1: bass clarinet signal outputs 1&2: basic electronics L/R stereo pair outputs 3&4: extra electronics L/R stereo pair
bass clarinet mic [c]	SD Systems LCM82B	2 mics are combined in 1 channel before going to interface
foot controller [d]	Keith McMillen SoftStep	This is a multi-sensor foot controller (5 sensors per button) which has lots of possibilities. I have 8 buttons free, the others I use for standard controls like audio on/off, resets, and switching pieces
PA	provided by the hall	I play concerts at locations with only two speakers available: your piece has to work in stereo, without a subwoofer [e]

for Marij van Gorkom

Shard

Amplified Bass Clarinet & Electronics

Electronics patch information

On opening the patch you will see the presentation mode, orientate yourself with the patch. You will see a readme sub-patcher open and find these instruction.

1. Press ESC (it will -68dB all live.gains and zero Delay 1 feedback integer)

2. Open the patching mode, in the centre at the top you will see the blue text buttons referring to the bangs that you should assign to your pedals.

****

(1) - Delay line 1 feedback control. Delay 1 is used in Section 1 and 3. This bang will allow you to cycle through 1-4 representing a range from 0.9-0.25; mainly for control in case of feedback.

(2) - Is your main control to cycle through the sections 1-4.

(3) - Is a complete OFF -68dB on all live.gains.

(4) - Is for testing your input.

****

3. Back to presentation mode, Drop your 7 Drone Files.

4. Press Space-Bar (It will 0.0dB all live gains and toggle Adc~ (when pressed again un-toggling Adc~)

5. Press output (dac~)

6. Test input with (10 INPUT ONLY)

7. Begin with Section Bang 1-4, starting at section 1

- I recommend a foot-switch for each of the blue text buttons. .
- Pressing ESC will -68dB all live.gains and zero Delay 1 feedback integer.
- Pressing space-bar will 0.0dB all live gains and toggle Adc~ (when pressed again un-toggling Adc~).
- Don’t forget to drop your drone files in to the “Drop Drone Files Here” box. Seven files at different lengths.

Benjamin Fox

Shard

Amplified Baritone Saxophone & Electronics

Pedal
FX1

Intensity of sound and energy
swelling dynamics

Thwack!

listen

Finger Noise
Reverse Slap

breathe

Finger Noise

Continue this cycle - vary the order, space and intensity of the gestures.

↓

Then add to cycle - any order.

Air Noise

Slap Tone

Open multiphonic
vary dynamic

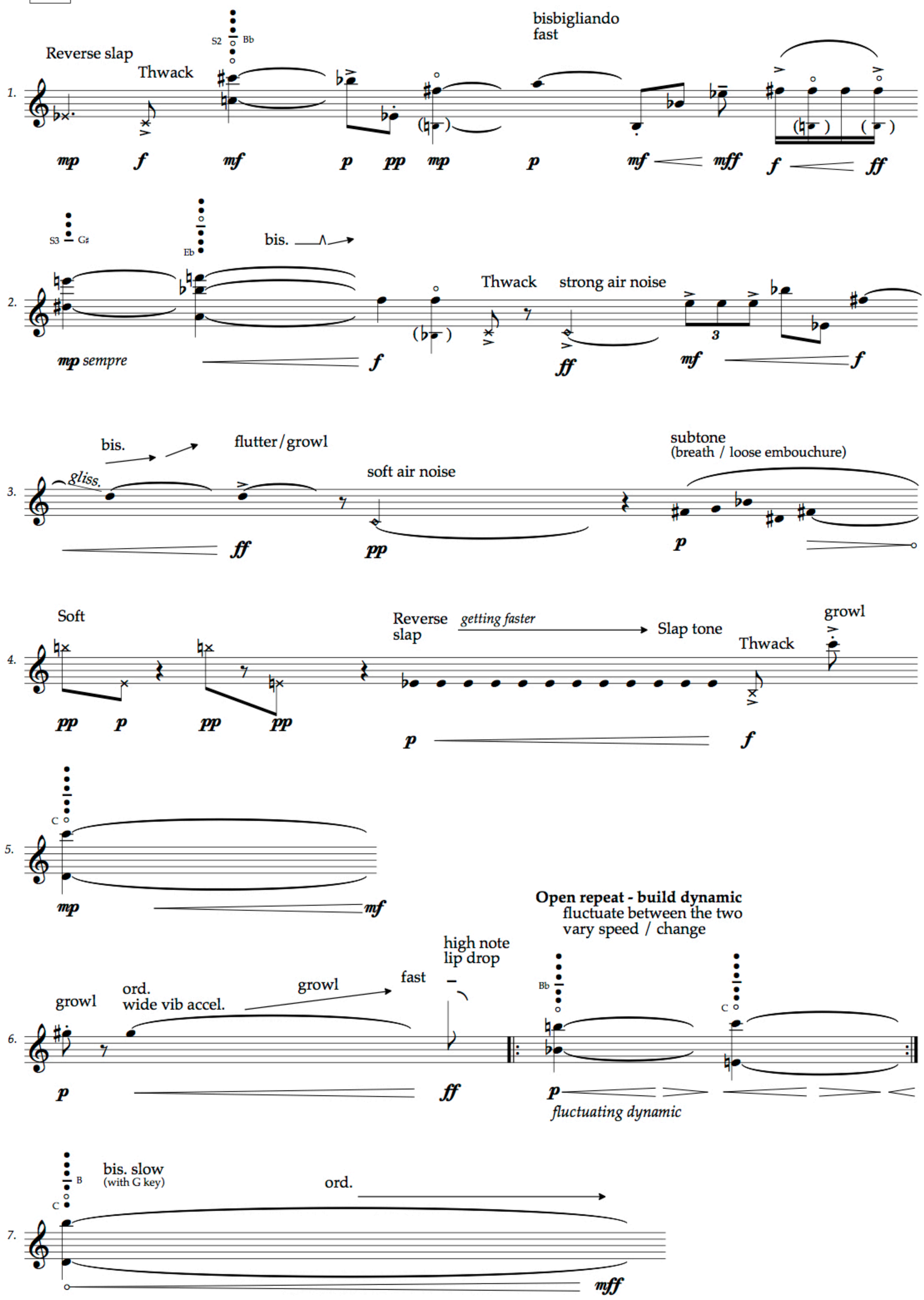
D multiphonic

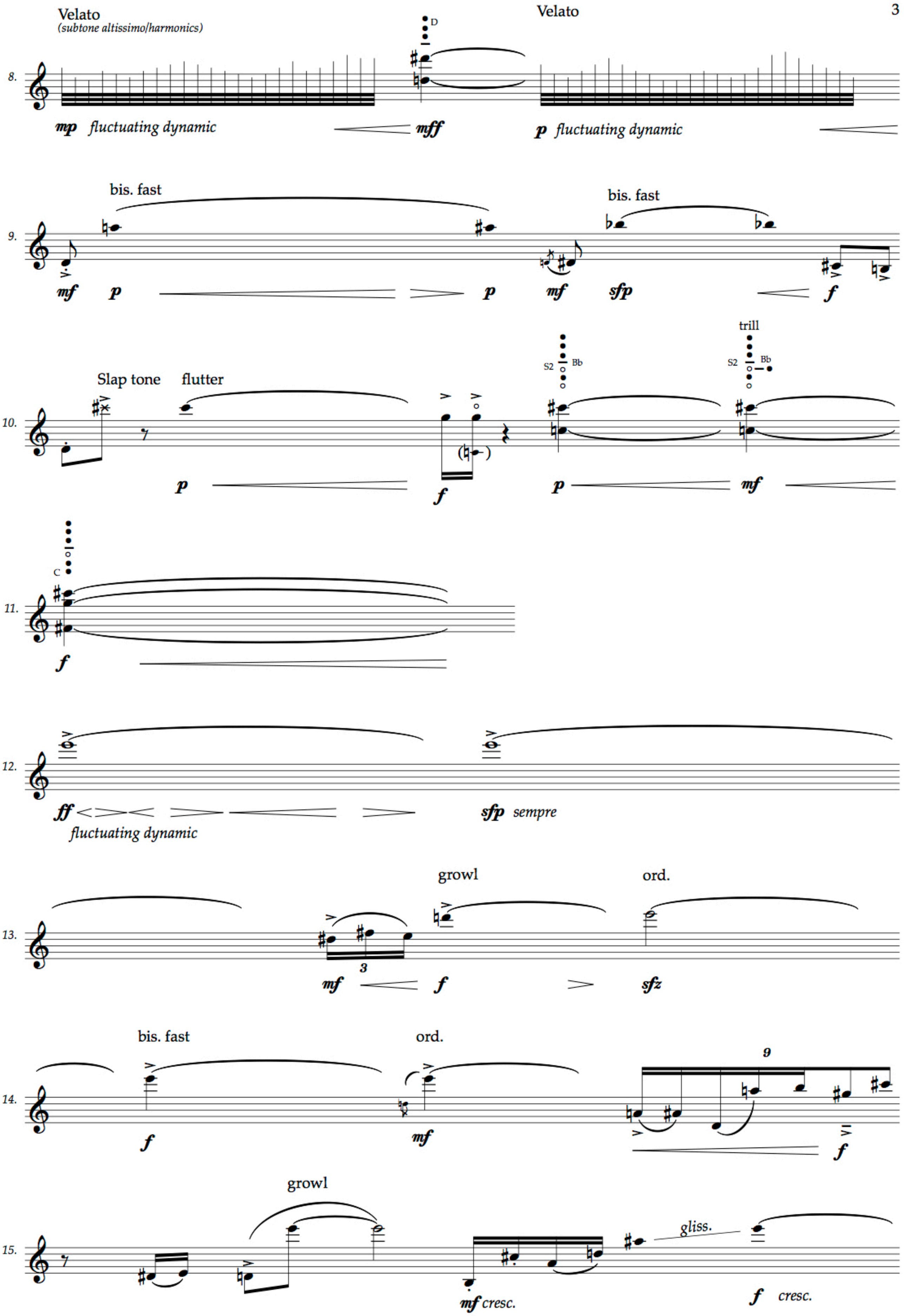
climax
to end with

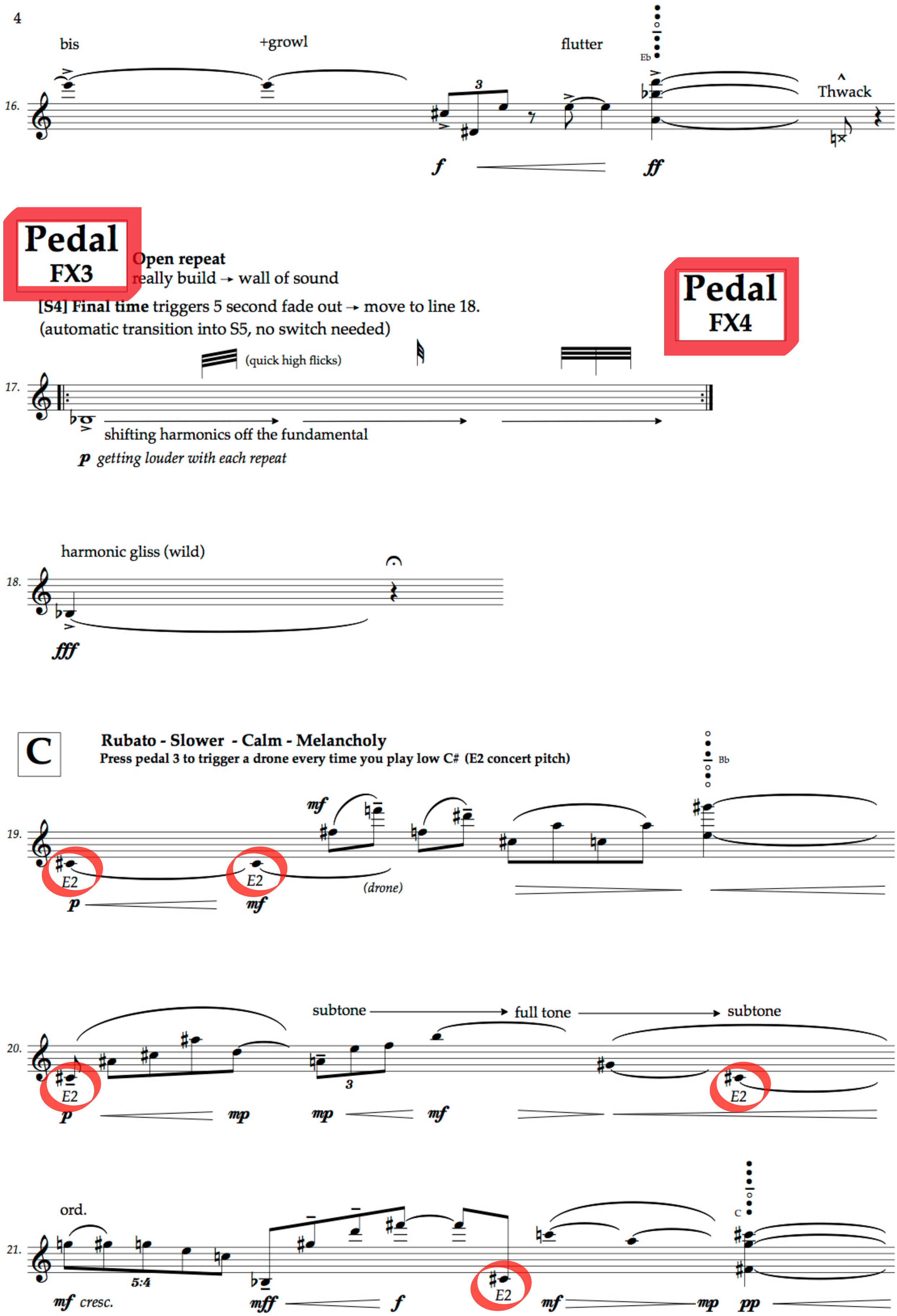
mf — ***f***

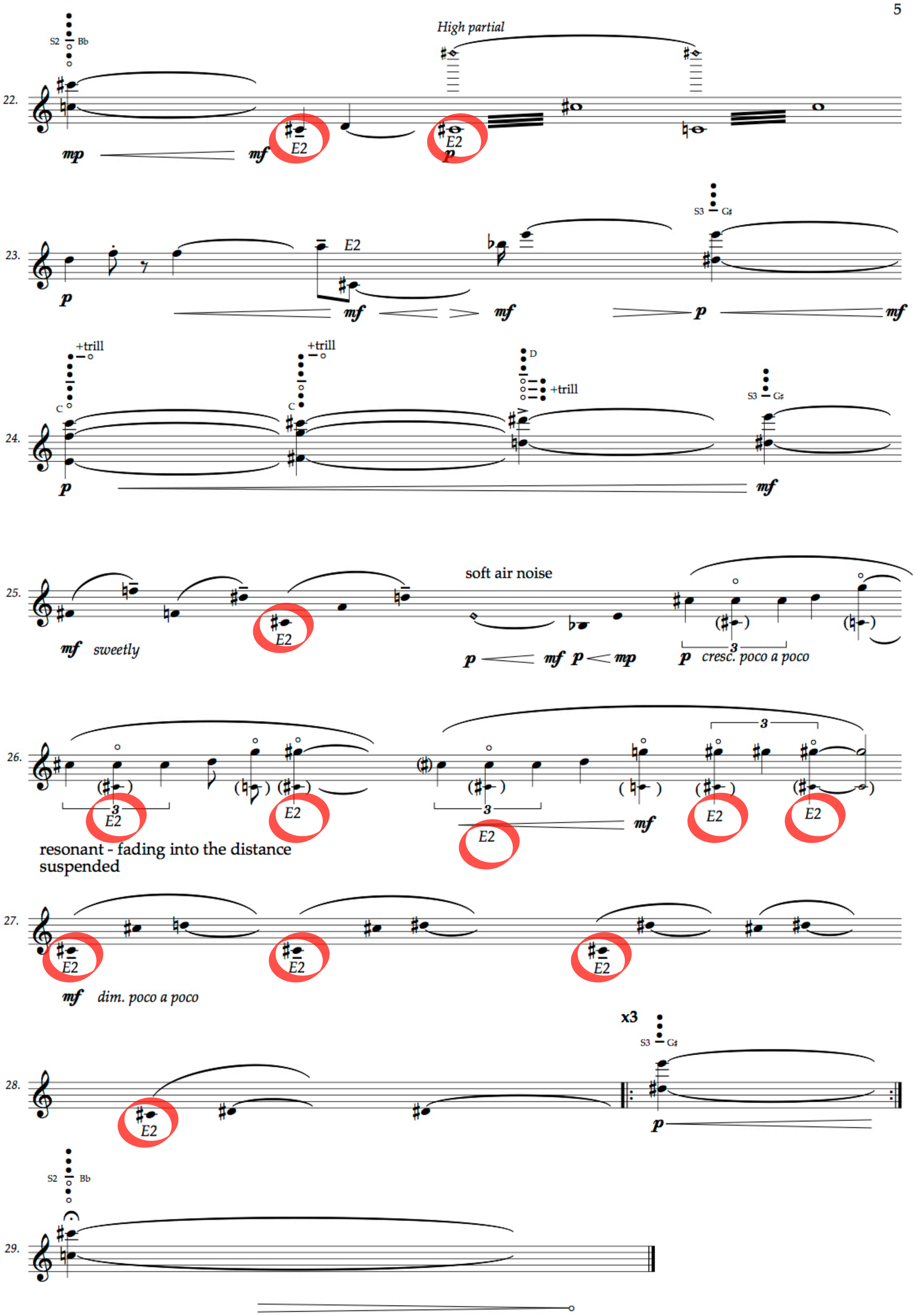
Pedal
FX2

2 **B** **an undercurrent of constant energy**
refraction - density - timbre

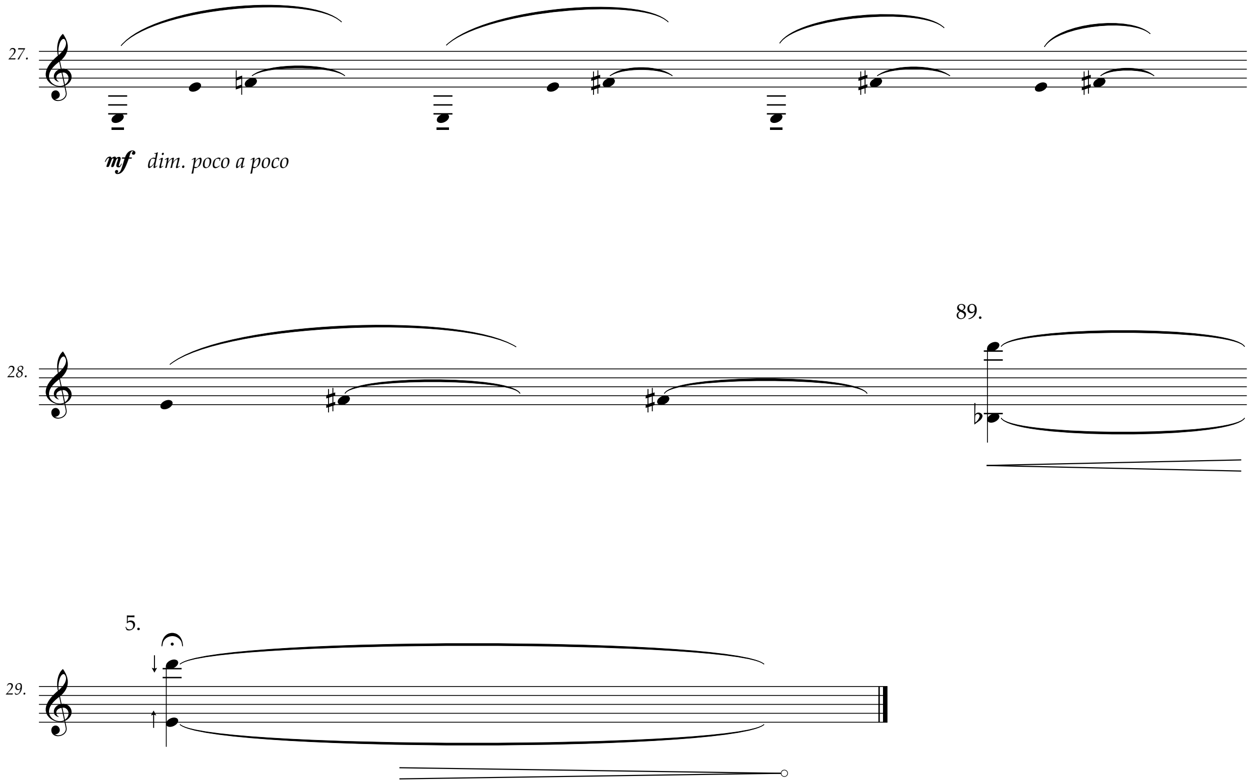



Velato
(subtone altissimo/harmonics)
8.
mp fluctuating dynamic
D
mff
Velato
p fluctuating dynamic
9.
bis. fast
mf
p
p
bis. fast
mf
sfp
f
10.
Slap tone
flutter
p
f
S2
Bb
p
trill
S2
Bb
mf
11.
C
f
12.
ff
fluctuating dynamic
sfp sempre
13.
3
mf
growl
f
ord.
sfz
14.
bis. fast
f
ord.
mf
9
f
15.
growl
mf cresc.
gliss.
f cresc.


bis
+growl
flutter
Eb
Thwack
16.
f
ff
Pedal FX3
Open repeat
really build → wall of sound
[S4] Final time triggers 5 second fade out → move to line 18.
(automatic transition into S5, no switch needed)
Pedal FX4
(quick high flicks)
17.
shifting harmonics off the fundamental
p getting louder with each repeat
harmonic gliss (wild)
18.
fff
C
Rubato - Slower - Calm - Melancholy
Press pedal 3 to trigger a drone every time you play low C# (E2 concert pitch)
Bb
19.
E2
E2
(drone)
p
mf
20.
subtone
full tone
subtone
E2
E2
p
mp
mp
mf
21.
ord.
5:4
C
E2
mf cresc.
mff
f
mf
mp
pp


High partial
S2 Bb
22.
mp
mf
E2
E2
p
23.
p
E2
mf
mf
S3 G♯
p
mf
+trill
C
+trill
C
D
+trill
S3 G♯
24.
p
mf
25.
soft air noise
mf sweetly
E2
p mf p mp
p cresc. poco a poco
26.
E2
E2
E2
mf
E2
E2
resonant - fading into the distance
suspended
27.
E2
E2
E2
mf dim. poco a poco
x3
S3 G♯
28.
E2
p
S2 Bb
29.

6 resonant - fading into the distance
suspended



D. Sara Belle

#Nothingchagesunwatched (2018) is an immersive, interactive, multimedia installation that seeks to explore, challenge and subvert the terms of engagement between the IRL and the URL, the real and the hyperreal.

In Real Life (IRL) we are subject to the moment in which we are physically present. We respond to the sounds we hear, the text we read and the images we see. Both physiologically and emotionally we interpret the world around us through these cues.

The URL, the online realm, frees us from the physical, time-bound constraints of reality. With a few taps of a social media app, we become curators of a new hyperreal experience, a new digital self, an alternate reality that is compelling, immersive, addictive.

'Follow', 'like', 'hashtag', 'favourite' are moments sampled from IRL. 'Caption', 'comment', 'share', 'consume' generate an algorithm. These moments are malleable, they change with each interaction and each consumed iteration. The mundane is made extraordinary; the extraordinary is now common, indelible. Both physiologically and emotionally, we respond.

#Nothingchangesunwatched invites you to be both auteur and audience in a space that blurs the border between the real and the hyperreal with an experience that is both subjective and objective. React. Interact.

The installation continues online**#nothingchangesunwatched**

Audio – composed and performed by Sara Belle.
Films - by Sara Belle shot on iPhone 5c, edited using Instagram and InShot photo editing app.
Text presentation – https://top-hashtags.com/instagram/& #nothingchangesunwatched devised by Sara Belle

E. Catalogue of documentation and materials

The table below is a catalogue of all the media files referenced in the text. These files may be found on the USB key accompanying the thesis.

Projects	Audio Files	Video And Image Files	Max Msp Patches, APP
Chelsea Flower Show	CFS	Brunel team 1 Brunel team 2 Brunel team 3 CFS1 CFS2 CFS3 CFS4	CFSPatch
Drama Student	HongyeAIFF (1 to 5) AlistarAIFF (1,2) I-HsuanAIFF(1 to 23)		Hongye& Alistar I-Husan
Improvisation Sensor Box			Improvbox
Matt London Shard	E2 Loren Matt Matt&Loren	Setup	Matt MattAPP
Hackney Clock Tower	Audio		HackneyClockTower
Sara Belle	Real and fake time 2	A1 A2 A3 A4 A5 A6 Sara1 Sara2	Sara1 Sara2

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3. Videos available in the documentation part of this thesis, (CFS3, CFS4).

4. Videos available in the documentation part of this thesis, (CFS1, CFS2).

5. The (Brunel team 1) video in the documentation part of this thesis is about the session in which Sonic Art students recorded samples of Dame Evelyn Glennie. There are two other videos (Brunel team 2 and Brunel team 3) which record the sessions we had in Lincolnshire.

6. Final Max patch is available in the documentation part of this thesis, (CFSPatch).

7. Audio File is available in the documentation part of this thesis, (CFS).

8. Final Max patch is available in the documentation part of this thesis, (Hongye& Alistar).

9. Audio files are available in the documentation part of this thesis, (HongyeAIFF 1 to 5 & AlistarAIFF 1,2).

10. Audio files are available in the documentation part of this thesis, (I-HusanAIFF 1 to 23).

11. Final Max patch is available in the documentation part of this thesis, (I-Husan).

12. Audio available in the documentation part of this thesis, (Loren, Matt, Matt & Loren).

13. Final Max patch is available in the documentation part of this thesis, (Improvbox).

14. Video available in the documentation part of this thesis, (Setup).

15. Audio available in the documentation part of this thesis, (E2).

16. Final Max patch and APP are available in the documentation part of this thesis, (Matt, MattAPP).

17. Audio available in the documentation part of this thesis, (Audio).

18. The final patch is available in the documentation part of this thesis, (Hackney Clock Tower).

19. Video examples and Audio available in the documentation part of this thesis, (Video: A2, A3, A4, A5, A6, Sara1, Sara2),(Audio: Real and fake time 2).

20. Video available in the documentation part of this thesis, (A1).

21. Max patches available in the documentation part of this thesis, (Sara1, Sara2).

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