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The absentee performer: the impact of replay on electronic music

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Abstract

In the first half of the 20th century electronic musical instruments were conceived as instruments that would be played by virtuoso performers. Yet these instruments had little impact on the development of music at the time. Many of them either resembled conventional control interfaces such as electronic keyboards or were free tone control interfaces such as the theremin, which had no precedent in conventional organology. Paradoxically it was the technology that was developed for archiving and reproducing music that had a more significant influence on the way electronic music was composed and performed.

Various types of recorded playback technology such as the turntable, magnetic tape and the digital hard disk became a format whereby composers could generate and sequence music using electronic processing and editing technology. Composers used the sound studio as a laboratory to explore the new frontier of captured sound as well as utilising playback as a means of performance including collaborations with live performers.

However it was the emergence of digital sequencing that made it possible for composers to explore interaction between live performers and electronics to the extent that the live performer could influence the playback system.

This thesis examines the art of replay in the context of works by composers of electronic music and documents the development of an interactive computer and live performer ensemble that uses digital sequencing and replay on a file-sharing network. The accompanying folio of works illustrates some of the creative possibilities.

Prologue

For many composers of electronic music, creative vision is closely allied to the exploration of technology and ways of controlling it. Yet new musical instrument technologies have been the catalyst for musical innovation in previous epochs. By the late 18th century, the industrial revolution enabled the production of many commonly used instruments to benefit from new manufacturing techniques thereby increasing their tone and range. Beethoven, for example, was the recipient of a new six-octave piano donated by Broadwood (Latcham, 1992, p. 527). His uncompromising use of this instrument in the last four published sonatas would not have been possible using contemporary Viennese pianos.

Electronic instruments in the early 20th century continued to expand the possibilities for musical expression. Perhaps the most successful was the Ondes Martinot, which offered both standard and microtonal pitch including its characteristic violin-like portamento. Assisted by these versatile attributes the Ondes Martinot has been used in many compositions throughout the 20th century (Bloch, n.d.).

However, some electronic instruments introduced unexpected possibilities for musical experimentation. Instruments such as the theremin did not sit comfortably within the orchestral framework like the Ondes Martinot did. The theremin, unlike violins and cellos, does not have the tactile feedback that assists performers to use standard tuning. Moreover, theremin intonation is further compromised when it is played in close proximity to other performers. Such limitations by no means prevented composers from exploring the choreographic nature of its interface. David Tudor and Gordon Mumma used theremins in their realisation of John Cage's *Variations V*

(1965). Such innovative applications of the theremin's technological idiosyncrasies extended the concept of musical performance. Dance movement became a way to play electronic music.

Experimentation with generic electronic technology became an integral process in the development of electronic composition to the extent that many composers created their own electronic musical instrument systems for live performers. Examples of compositions include Mumma's *Hornpipe* (1967) for French horn and electronics, Joel Chadabe's *Ideas of Movement at Bolton Landing* (1971) for programmable synthesizer and live performer, and Claude Risset's *Voilements* (1982) for tenor saxophone and tape.

Through out this thesis I use the term 'replay' to refer to the new relationship between musicians and mechanical music making and in <u>Chapter 1 The Absentee Performer</u> the term 'absentee performer' is introduced to refer to the mechanical agent in this relationship. Early forms of replay can be found in the works of Antheil (*Ballet Mecanique*, 1924) and Nancarrow (*12 Studies Volume 1,* 1949) which used player pianos as a medium of performance. These works pre-empted forms of electronic music making where human performance could be replaced entirely by electro-mechanical methods to sequence music using magnetic tape. They also pre-empt innovative performance scenarios where human performance is combined with the use of record players and magnetic tape recorders as an integral part of the process of music making. In such scenarios a human performer interacts with an absentee performer via pre-recorded media.

Chapter 2 From Sequential Access to Random Access discusses the way that composers have used technology to create processes that combine composition and performance. Through experimentation with electronics composers developed new forms of music whose structure and sound had no musical precedent. The music they produced was determined by a configuration of electronic components and devices rather than a traditional score.

My earliest encounter with such technology took place in 1985 when I produced my first piece entitled *Wandering Stars* using the Serge Modular and Driscoll voltage control synthesisers as an undergraduate student at the Sydney Conservatorium. A chance encounter with the patching composition language called Pure Data written by Miller Puckette immediately rekindled memories of that formative experience with voltage control technology. The desire to revive that experience and to see how composing in Pure Data might be combined with classically trained performing instrumentalists has been the catalyst for a folio of interactive work that is now the companion to this thesis. *Wandering Stars* is included in the folio.

Interactive instrument systems continue to challenge traditional views of musical performance. This is inevitable when there is a divide between practitioners of interactive electro-acoustic music and the institutional focus on traditional orchestral instruments and their historical repertoire. This thesis asserts that interactive computer technology provides fertile ground for creative innovation using traditional instruments and in Chapter 3 Music for a Networked Ensemble discusses the creation and realisation of a composition for live instrumentalists and electronics called *Trio for Two Musicians*, composed using Pure Data. The principal feature of this work -

for two performers playing traditional instruments - is live interaction with musical information shared via a computer network. It is one of several creative works included in the folio.

Throughout this thesis italics are used to indicate both the titles of compositions and the names of Pure Data - Pd - objects. Wherever italics are used the intention will be clarified by the context. The thesis contains references categorised as books, journals, recordings and scores to enable the reader to differentiate between the musical literature - in both print and recorded forms - and literature related to music.

Chapter 1 The absentee performer

1.1 The development of replay composition and performance

Recording in the 20^{th} century has had a significant impact on composition and performance. Bartok, for example, was able to transcribe Magyar folksongs from Hungary by recording authentic performances (Bartok recordings, 1995) on an Edison cylinder and quoting them in his own compositions *(For Children,* 1908-11).

In 1916 the Edison Phonograph Company released the diamond stylus phonograph. It was a significant breakthrough in sound reproduction that was marketed as a musical instrument capable of recreating music. A brochure produced by the Edison Phonograph company states:

> *"It is a means by which the joy of genuine music has become a universal possession. .... He has established a new art; music's recreation".* (Liebert, 2006)

The phonograph became a means of archiving musical performance. The term 'recreation' shows that the intention was to market the nostalgia of authentically captured performances by well known artists associated with concert halls such as Carnegie Hall. The soprano Marie Rappold from the Metropolitan Opera in New York participated in a demonstration of the Edison phonograph at Carnegie Hall performing alongside her own recording. Drawings of her standing beside the phonograph featured in one of their brochures reinforcing the image of the virtuoso producing the sound.

However, Mark Katz (2004) in his research of these early recordings suggests that the recorded medium influenced music through what he terms 'the phonograph effect'. He asserts in relation to the violin that excessive vibrato became a fashionable playing style because it was easier to recognise and appreciate the violin that way on phonographs with poor sound quality. Whether he is right or wrong, it does highlight that the replay of recorded sound is disconnected from the visual actions that produced it. The Canadian composer Murray Schafer used the term ‘schizophonia’ to describe this disconnection (Schafer, 1969). Despite the imputations of this term, disconnecting the actions of a performer involved in producing the sound allows the listener to focus on its sonority.

In the twentieth century noise became an important part of the ideology for discovering music in all types of sound. Traditionally what had been considered musical excluded sounds other than those made by a musical instrument or the singing voice. The idea of creating music that potentially included all sound was a central thought in Russolo's 1913 manifesto on the art of noise. He states:

> *“And so was born the concept of sound as a thing in itself, distinct and independent of life, and the result was music”* (Russolo, 1913).

Wolpe applied this thinking in relation to the record player in 1920 when he used eight record players to play parts of Beethoven's 5th symphony at different speeds at a Dada concert (Lecture on Dada 1962). At the 1930 Neue Musik Festival of contemporary music in Berlin, Hindemith presented two works called *Trickaufnahmen* using the sounds of a xylophone, voice and cello (Holmes 2008). Alex Ross in his article entitled ‘The record effect’ (2005) states that a young boy named John Cage was present at these performances. Cage wrote a piece called *Imaginary Landscape No 1* (1939) for turntable consisting of test tone recordings. In the work of Cage the phonograph became the catalyst for musical experimentation. The record player had become not just a passive medium for archiving treasured performances but an active means of composing and performing.

1.2 The turntable performance

The speed control of a turntable came to be seen as a mechanism by which pre-recorded sounds of the phonograph could be altered. Composers continued to develop new music that used turntables played as musical instruments. One is Phillip Jeck who composed *Vinyl Requiem* (1993) for 180 record players, 12 slide-projectors and two movie-projectors. Another is Janek Schaefer, not to be confused with either Pierre Schaffer, the French composer or Murray Schafer, the Canadian composer. He is a turntable composer who builds and modifies turntables including twin and triple arm 'vari-speed' versions. His composition *Pulled Under* (2002) combines the use of the turntable with his own field recordings in a comprehensive 'musique concrete' performance. Bernard Lang has used the turntable in a traditional concert hall setting by combining turntables with an orchestra. His work *Dw8* (2003) was composed for two turntables and orchestra and was premiered by Symphonie Orchester des Bayrischen Rundfunks of Munich featuring two turntable virtuosos Marina Rosenfeld and Dieter Kovacic. Such performances demonstrate how the turntable has evolved since its invention more than a century ago: once a device that was initially used in music for documenting performance, now an instrument of performance virtuosity.

1.3 **Edited media: from production to performance**

Composers used recorded music on magnetic tape either as a replay compostion exclusively or as a tape part presented alongside live performers. The coexistance of tape and performer reinforced the impact of the absentee performer as musicians skillfully performed in conjunction with the unalterable 'concrete' performer.

Magnetic tape was not considered a musical instrument as the turntable had become but it did take the disconnection of sound and action further by cutting and splicing small portions of audio into musical sequences. The tape composition called *Etude* *aux objets* (1959) by the French composer Pierre Schaeffer illustrates this process. His recorded objects were recordings of musical instruments. The sounds were not subject to any audio transformation other than being spliced and overlaid with each other and yet they are mostly unrecognisable.

Composers such as Berio, Varese, Boulez, Stockhausen, Xenakis, Ussachevsky and many others became well known for their innovative use of sound transformation technology. Processes included sound and pulse generators and filters resulting in register shifts, timbral variations and pitch to pulse transformations. Stockhausen's *Kontakte* (1960) for tape, piano and percussion is an example of this. But there is a divide between the production of a tape composition and its presentation. The concert audience is absent during the production process so it does not see the actions that produce the sound.

The creative process of producing tape music would often involve a series of actions by the composer using sound processing devices. For example, the production of a tape master involved using a patch-bay to route audio signals that are controlled using a mixer. These processes were often used in performance as live electronics without the use of replay. Digital processing has brought the control of live electronics and the control of replay together.

The functions of an analogue mixer have been increasingly replaced by digital audio mixing requiring less human intervention. The digital audio workstation (DAW) combines signal processing with automation; sequences triggered on cue by live performers now appear to an audience as part of the musical performance. Laptop computers have become musical instruments often played to a public audience. The Princeton Laptop Orchestra (PLOrk) is an example of this. Each workstation offers several forms of live performance control such as touch screen and infrared sensing and accelerometers (Smallwood et al, 2008).

Commercially available software such as the application called *Live* by the software company Ableton is capable of digital audio production in live performance. It has appropriated technology once restricted to broadcast radio studios in Paris, Köln, Milan, London, Warsaw, Tokyo and other centres where electronic music flourished in the 1950's and made it accessible empowering more composers to participate in the practice of electronic music where performance and automation integrate easily.

In the accompanying folio of works there is a composition called *SHarp Attack* for harp and a computer sound-processing operator. It uses studio processing as a real time performance. The next chapter discusses the impact of emerging digital technologies on the development of electronic composition and performance.

Chapter 2 From sequential access to random access

2.1 Instant access

Computer technology in the latter part of the 20th century fundamentally changed the composition and performance of electro-acoustic music. The computer introduced new methods for accessing and processing information. This was achieved with microprocessors capable of processing multiple instructions instantaneously. Previously, access to information was sequential and required human intervention with or without mechanical assistance. The turntable and the magnetic tape recorder described in the previous chapter are examples of sequential access.

Computer technology overcame the barrier of chronological time making possible instant processing of multiple command structures and instant access to file information. Access at this level enabled composers to generate and transform sounds, construct musical sequences and apply abstract musical processes in ways that were previously unachievable.

The transition from sequential access to random access technology in the second half of the 20th century has been part of an important paradigm shift in the development of electro-acoustic music. This shift has had a profound impact on the sonic organisation (Wishart, 1988 pp. 26-27) and performance of music.

There are many ways this can be demonstrated. However an extensive survey of electro-acoustic music is well beyond the scope of this essay. In order to illustrate the transition from sequential to random access it is enough to compare a few salient examples of related compositions each representing an important milestone in different stages of the development of electro-acoustic music.

The examples used are discussed in three ways:

- Compositional methods of sound transformation
- Simultaneous composition and performance
- Interactive human/computer performance

2.2 Compositional methods of sound transformation

Various forms of replay technology have directly influenced methods of composition. Luciano Berio and Trevor Wishart are two out of many electronic composers who worked with replay technology to realise their musical ideas. Berio's *Thema: Omaggio a Joyce* (1968) and Wishart's *Vox V* (1986) are replay compositions that use the human voice as a sound source. A comparison of these works shows the difference between analogue and digital sound transformation technology and the way each composer has responded to the possibilities at their disposal.

Both composers share the concept of creating metaphorical transformations of the sound derived from its initial context. Berio established his metaphor in *Thema* by recording a female voice reading a text from Joyce's Ulysses. From there the textual reading is transformed into a musical abstraction consisting of the voice divided into groups of sounds superimposed in a fugal structure.

Berio explains that this counterpoint of sound is derived from the counterpoint of characters and ideas that exist in the original text. He used splicing, frequency transformation, time modulation and filtering to create his own musical syntax based on the coexistence of voice fragments. In his own words:

> *"We pass from a poetic listening space to a musical listening space. This musical listening space is based on the poetic material, on an object which is transformed and becomes music"* (Murphy, 1999).

In *Vox V*, Wishart constructs his metaphor as spoken words that are transformed directly into discernible sounds. Each sound is symbolic of the meaning of the word it represents as spoken words morph into the associated sound. In order to achieve this he used sample-based granular synthesis.

Both these works create musical meaning through sound transformation, but there is a distinction between the abstract meaning of *Thema* and the literal narrative of the voice morphosis in *Vox V*. It is the technology of granular synthesis that inspired and enabled Wishart to take a different approach. He has effectively spliced recorded audio in ways that would be impossible using conventional magnetic tape splicing techniques. Digital techniques for granulating sound sources i.e. converting a small section of tape into thousands of tiny grains of sound allow the composer to apply an algorithmic formula that will gradually transform one sound source into another.

It is clear from this comparison that the digitisation of sound has made it possible to develop new methods of composition, opening up new ways of transforming sound. Wishart expresses it in this way:

> *"The computer opens up areas of compositional exploration that were previously inaccessible …. Areas of sonic organisation previously inaccessible to composers through the existing media of notation can be explored, opening a new world of dreamed of, but unsung possibilities"* (Wishart, 1988 pp.26-27)

This does not imply musical obsolescence on works created for magnetic tape. Creative works are idiomatic to the technology that was used to create them. But ultimately works like *Thema* are still remembered long after the techniques that were developed to create such works have become arcane or are no longer available. The same might also be said of *Vox 5* within a few decades.

2.3 Simultaneous composition and performance

The instantaneous response of random access has enabled real-time computer processing to become a part of an electronic music performance. Nicolas Collins programmed algorithmic processes to search the broadcast spectrum for audio program material which became part of his piece called *Devil's Music* (1985). Collins generates music in real-time by programming the computer to select frequencies strong enough to provide the best audio loop source. The computer responds by sampling, looping and transforming the sounds thus creating a parody of the radio medium by turning it into something that resembles a dancing marionette. These spontaneous and aleatoric apparitions of the absentee performer echo Cage's *Imaginary landscape IV* (1951) for 12 Radios and 24 performers. For Cage, the technological process relied on human intervention of 24 performers to control 12 radios and create music; *Devil's Music* required no such human intervention.

In *Imaginary Landscape IV* Cage was exploring indeterminacy. As a response to a comment made to him by Henry Cowell, Cage stated

> *"It is thus possible to make a musical composition the continuity of which is free of individual taste and memory (psychology) and also of the literature and 'traditions' of the art. The sounds enter the time-space centered within themselves, unimpeded by service to any abstraction, their 360 degrees of circumference free for an infinite play of interpenetration.* (Cage, 1961 pp.57-59)

Furthermore, through *Imaginary Landscape IV*, he highlighted the limitation of radio, which had until that time only been used as a medium of distribution rather than interaction, a medium for communication in one direction rather than two. By contrast with *Imaginary Landscape IV, Devil's Music* is less indeterminate. For Collins, the computer was able to realise specific musical outcomes within the framework of an aleatoric process. He blatantly allows his 'taste' to slip through. He states:

> *"I wasn't John Cage, but I was very interested in his idea of creating music that happened without taste being there all the time. Maybe what your taste did was to pick the departure point."* (Duguid, 1995)

For a new generation of composers random access was the underpinning factor that provided a plethora of new possibilities to create versatile instrument systems capable of simultaneous composition and performance. Like *Imaginary Landscape IV*, Collins takes control of a medium known for its power to control through the influence of widespread one-way communication.

2.4 The interactive human/computer performance

Collaborations between human performers and automated technologies have expanded and enriched the performance of electro-acoustic music with new possibilities. Prior to the electronic age, composers had experimented with automated performance. Mozart, for example, composed two *Fantasies* in F minor k.594 and k.608 (Hyatt King, 1977) for mechanical organ. The invention of the player piano at the turn of the 20th century was an acoustic appearance of the absentee performer. Like the turntable, it too was originally designed to reproduce musical performances for domestic entertainment. Composers such as Antheil and Nancarrow explored the player mechanism as a technology for composition which was later extended by Alistair Riddell (1982) as an electronic hammer action. The early works also helped to establish an idiom of player piano composition that laid groundwork for composers like James Tenney, Jean-Claude Risset and Kyle Gann.

The early player piano typifies sequential access. The mechanical rotation of the piano role produced automated musical expression that is independent of human physiology. Nancarrow's *12 Studies for Piano Player* (1949) explores complex poly-rhythmic and multi-voiced musical sequences unplayable by a human. The advantages of random access become apparent in *Duet for One Pianist* by Jean-Claude Risset (1985) where the computer exercises control over a computerised piano action. Risset has programmed the computer to respond in real-time to the actions of the live performer. Each of the eight pieces uses a different algorithm to explore various musical aspects of the performers interaction. The result is a hybrid instrument combining a traditional keyboard with a computer system capable of contributing meaningful musical responses.

There have been many extended instrument systems. Examples include: an amalgam of purpose-built analogue hardware used in live performance by Gordon Mumma playing French Horn in his own composition *Hornpipe* (1967), or the collection of instruments known as the Expanded Instrument System (Pauline Oliveros 1978); or they may also include sensing hardware systems such as the Hypercello, created by Todd Machover (Machover, 2007) or the SBass created by Curtis Bahn (Bahn, 2001); or they may also include the virtuoso performances by David Shea using a stand-alone sampling keyboard (Shea, 1999). Combination of legacy technology and computer interaction becomes the focus of creative work discussed in the next chapter.

Chapter 3 Music for a networked ensemble

3.1 Emergence of the absentee performer

The principal focus of my creative folio is a form of electronic composition known as algorithmic composition where musicians interact with live signal processing algorithms. The absentee performer first appeared when I created algorithms that formed the basis for two of the algorithmic works entitled *Glimpses in 1 second* for guitar and computer (2006) and *Pure Melody* for solo flute (2006). As the algorithms used in these works were further developed, the concept of the absentee performer became clearer and gave rise to a new work entitled *Polymetric Study* for flute and violin (2009). It is a preliminary study written to test the playability of the onscreen notation system I developed using frequency numbers to indicate pitch. It is called the performance controller and is discussed further in this chapter. It was performed by student musicians with no previous experience of microtonality. A year later after continued experimentation with the software I found a way to use network commands to communicate between machines and this resulted in a second work entitled *Trio for Two Musicians* for guitar and violin (2010). All four works are found on tracks 4 - 7 on the accompanying CD. The folio also includes some concert works that involve musicians performing with electronics as well as a work that is purely electronic without live concert performers.

3.2 The absentee performer joins the ensemble

Throughout this chapter I explain the absentee performer and how it joins the ensemble using *Trio for Two Musicians* as a case in point. It is based on the same compositional framework as *Polymetric Study* for flute and violin but extends it by adding a third performing voice which is generated from a looped sample of one of the instrumentalists captured in realtime.

In both compositions each player's instrument is connected to the audio input of a computer workstation. This allows the computer to track the input frequency and capture audio input produced by each live player. In both compositions each computer is connected via a network connection as shown in Figure I.

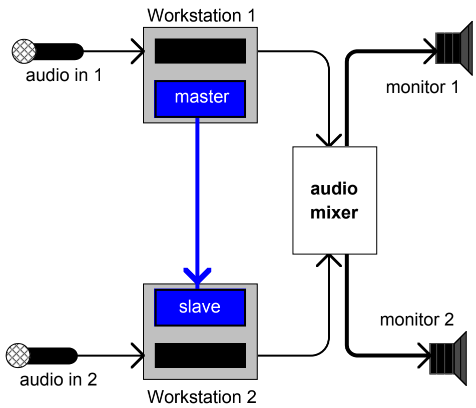


Figure I. Ensemble system showing audio and network configuration. Audio signals are shown in black. Network communication signals are shown in blue.

Each computer acts like an assistant that guides the players' intonation and rhythm. But it does more than simply assist the player. The software also generates two 'cues' to control audio. One captures a one-second audio sample from the live performer every ten seconds; the other generates a canon where audio is replayed with delay times that are changed at various points creating the polyphonic interplay of rhythm and harmony.

The final work is entitled *Trio for Two Musicians* because even though there are only two live performers present there are three audible 'voices' each performing independantly. The two live performers produce audio processed by a computer network. Audio is sampled and control information extracted using a PD object called fiddle~. Both computers are linked via a network that allows musical information to be passed from one computer to another and an additional 'voice' to be generated in realtime. Both computers communicate via a network. Frequency values extracted from audio played by one performer are sent from the master to the slave and used to modify audio produced by the other performer. The result is a third ‘voice’ that is replayed by the slave computer independently of the live performers. This is the absentee performer.

Both compositions *Polymetric Study* and *Trio for Two Musicians* were realised in Pure Data, or Pd, a computer music programming language developed by Miller Puckette. Pd was used because it has tools like *fiddle~* that track and analyse the audio signal as well as *netsend* and *netreceive* which allow timing and control information to be distributed via a network using the User Datagram Protocol (UDP) (Reed, 1978).

3.3 Performance controller

A user interface on each computer presents each player with instructions that function like the parts of a traditional music score. The performance controller is shown in Figure II.

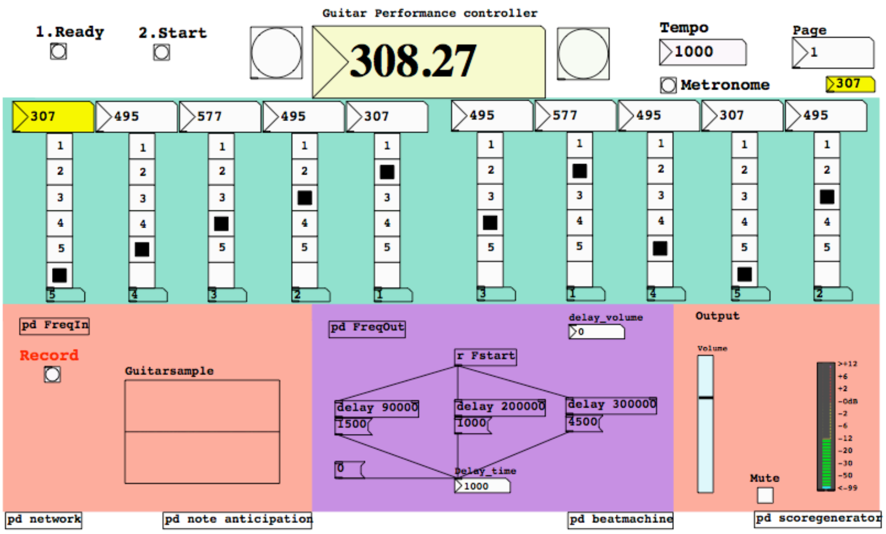


Figure II. Performance controller.

The numerical values displayed originate from sub-patches containing the command objects that generate the values. They are not in view so that it is easier to use the controller. The sub-patches are shown in appendix A.3 to A.6.

The performance controller provides metronome ‘cues’ that function like the conductor of an ensemble. It also presents each player with a frequency readout for each note they play.

3.3.1 Synchronising parts

The network is initialised when the ‘ready’ button on the master device is pressed. In Figure II this is labelled ‘1. Ready’. By pressing it both computers become connected allowing them to send and receive data. The master device also generates timing information to synchronise both computers.

3.3.2 The part

The musician connected to the master device commences the performance by pressing the ‘start’ button on their display. Using their instrument each player then reproduces the frequencies listed in each of the ten number boxes from left to right. Each note is held for one of five specified durations. These are displayed using a vertical radio button. The duration is the number of metronome pulses selected in the vertical radio button, the shortest being at the top and the longest at the bottom.

Figure III shows duration selected using radio buttons with corresponding duration values in traditional notation.

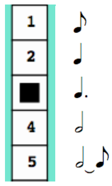


Figure III. Duration values

According to duration values shown in Figure III, the one-screen snapshot of the Performance Controller shown in Figure II are follows: 2 5 4 1 3 5 4 1 3 2. This can also be represented in conventional notation as shown in Figure IV.

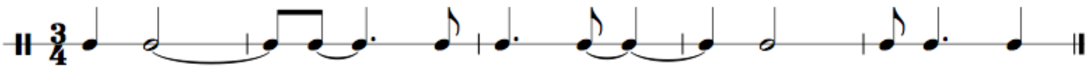


Figure IV. Durations shown in the Performance Controller expressed using traditional notation.

Expressing this using conventional notation requires a metrical sub-division of the rhythmic phrase indicated by bar lines that implies a hierarchy of strong and weak divisions within the metre. Or it may require a change of time signature. Either requirement may be a distraction for the musicians playing such rhythms. However in rehearsals and performances of *Polymetric Study* and *Trio for Two Musicians* playing such rhythms posed no problems for performers reading vertical radio buttons.

In *Trio for Two Musicians* the use of vertical radio buttons to represent duration allows the musician to conceptualise rhythmic values numerically rather than as duple divisions of a whole note value as found in traditional notation. This approach to rhythm is based on additive metrical groupings. Such a linear approach to rhythm is also common in traditional Indian music as well as in music elsewhere in Asia (Montford, 1985). Additive rhythmic devices inspired both Cage in *Three Dances for 2 Amplified Prepared Pianos*

(Nichols, 2002 p.80) and Messiaen in *Oiseaux Exotiques* (Simundza, 1988 pp.53-73) who appropriated them using conventional notation. And jazz musicians commonly construct such rhythmic groupings - intuitively and unencumbered by conventional notation.

3.3.3 Tempo

Each part in the score is played at a different tempo, the master at crochet equals 60, the slave at crochet equals 75. The master part is displayed in four screens, each lasting 30 seconds. The slave part is displayed in five screens, each lasting 24 seconds. Both parts are started in sync by a signal sent via the network from the master device. The master is driven locally by a metro set to 1000 milliseconds while the slave is driven locally in Pd by a metro set to 1250 milliseconds. This ensures that both parts end together.

In practice this approach has made it surprisingly simple for players to perform complex polymetric sequences as an ensemble. The performance controller provides a metronome that allows each player to play with an independent tempo yet remain synchronised with the ensemble.

3.3.4 Intonation

Each musician is guided by a live readout of the frequencies they play. The frequency appears in the largest number box shown in Figure II. Representing pitch as frequency gives players a precise indicator of intonation that conventional notation alone does not convey. It also allows the use of frequencies other than those associated with the standard 12-tone division of the octave. Players become more versatile and develop aural acuity as they attempt to reproduce frequencies specified in the score using extended playing techniques such as microtonal fingerings that are now part of traditional instrumental training (Bartelozzi 1967).

The format in which duration and pitch information is presented in the numerical read-out is elementary but has proved to be useful as a training tool for traditional instrumentalists learning to play non-standard rhythms and playing music in non-equal temperament.

3.3.5 The third voice

The performance controller is configured to replay audio samples made by recording fragments of live performance. One-second samples are recorded automatically every 10 seconds on the slave device. The frequency value from the master device is sent to the slave and is used to set the playback frequency of the looped sample. The sample display is shown in Appendix A.2.

Throughout the performance a one-second sample of the live performer is recorded every 10 seconds on the slave device. The process is triggered automatically when the start message is received from the master device. In performance the display changes every ten seconds as a new sample is recorded and looped. A record button also allows the player to test for signal. Not visible to the performer are the Pd sub-patches FreqIn which records the sample and FreqOut which loops the sample. The canvasses of both sub-patches are located in Appendix A.3 and A.4.

A third part or voice is created by modulating the amplitude of a live audio sample using a sawtooth waveform generator. This is a well known technique called amplitude modulation where the level of the carrier signal (live audio sample) is modulated by a program signal (sawtooth wave).

In this case the master device controls the frequency of the sawtooth signal. This modulates the amplitude of the sampled waveform. As both carrier and program have frequencies in the audio range the resultant side-bands are heard as a timbre distinct from the timbre of the other two instruments. The live audio sample and the program signal combine to create an audio signal whose timbre is enriched by virtue of the carrier signal being a sampled sound. The resultant timbre is the product of two musicians, one providing the audio sample, the other playing through the master device to control the frequency of the modulating waveform.

Amplitude modulation results in the creation of an additional voice that is generated by two ensemble contributors. The result is like a third member of the ensemble made possible by the marriage of algorithmic programming and live instrumental performance and extends the concept of orchestration associated with traditional concert instruments.

3.4 The network ensemble

Trio for Two Musicians sets out where *Polymetric Study* left off and created a musical network environment that introduces a compositional device that is like file sharing. A precedent for a networked ensemble is the collaboration between members of The League of Automatic Music (Bischoff Gold Horton, 1985). Each composer sent information to one another via serial connections that configured three KIM-1 microcomputers in a primitive network. Network interaction in *Trio for Two Musicians* connects performance control and the sounds produced in a different way. A parameter of sound produced by one player, viz. frequency, is used to control the timbre of sound produced by another. Like the phantom pianist in Risset's *Duet for One Pianist* the absentee performer implemented in *Trio for Two Musicians* serves to demonstrate that it is becoming more difficult to distinguish between play and replay technologies. In the context of my work the absentee performer is the bi-product of interaction between live players interconnected in real-time. Its performances always leave the way open for unanticipated surprises for each of the live performers and the musical effect exceeds the familiar transformations of sound normally associated with electro-acoustic instruments. It is this interactive relationship that forms the main focus of the work in the creative folio.

3.5 Life Expectancy of the Absentee Performer

The performance controller used in *Trio for Two Musicians* has been realised in several versions of Pd. It was developed using version 0.37, performed using version 0.41 and tested using the extended version 0.42. Providing that the objects used are not made obsolete in subsequent versions the life expectancy of the application is assured. The full list of objects used can be found in Appendix A.7.

Epilogue

Computers continue to offer composers ways to create music that include the capability of generating musical sequences at the moment of performance as well as creating works that are recreated using automated processes. The possibilities of algorithmic sequencing using computer technology have extended the boundaries of contemporary performance in much the same way that the introduction of magnetic tape extended the boundaries of experimental composition over a half a century ago. Today the convergence of the digital and audio technologies has removed many of the distinctions that once existed between analogue and digital worlds.

Digital music technology is now developed to meet the broad needs of a consumer market. This has become a fertile ground for a new genre of musical works that extend standard practice and exceed current expectations of musical performance. Digital technology has introduced communication protocols that in turn allow a greater degree of musical interaction between the machine and the musician who uses it. This introduces new possibilities for performance variation and improvisation where the creative role is no longer the sole prerogative of the composer.

Trio for Two Musicians sits within this frame-work of creative development. It appropriates generic network protocols as a means of communicating between computer devices. It uses a live interactive and programmable graphic display as a means of communicating between the musician and computer. It allows interactive musical information sharing to take place in real-time as an integral part of performance interaction.

Interaction with technology was an initial form of creative exploration in the early compositions of my portfolio. One example of this was the realisation of the Brecht and Eisler song *On Suicide* (1942) performed by the soprano Karen Cummings. In this performance I interacted with the dramatic actions of the live performer by controlling computer-generated sound. Another example is *SHarp Attack* (2004) for harp and computer. It explored automation as a means by which the sound of harp strings could be altered. The computer was able to remove the attack sound of each string through a controllable noise gate and extend the natural length of the decay through an applied delay effect. With the sound of the attack removed and the decay sustained, the listener's focus was directed towards the timbral characteristics of the harp strings.

Glimpses in 1 second (2006) for guitar and computer is a system for improvisation between an acoustic musician and the computer. The computer listens to the guitar by recording and looping samples. A frequency controller under the influence of a random number generator continuously alters the replay of the sample. The musician listens to the 'computer responses' and uses the computer's unpredictable replay as a guide for continued musical improvisation.

*Pure Melod*y (2006) for solo flute is another work for an acoustic instrument and computer that uses the same interactive improvisation process as the previous piece. It goes further by exploring the ways in which a traditional acoustic orchestral musician with little or no experience of electro-acoustic music can integrate live performance with computer technology. In this scenario, the flute and the computer became an extended instrument system.

Inspired by the outcomes of *Pure Melody*, the work *Polymetric Study* features a musician playing a conventional instrument assisted by a graphic display in order to play a sequence of non-standard pitch frequencies accurately.

The performance controller was significant because it enabled a traditional instrumentalist to explore microtonality with precision in a way that was previously impossible. An important aspect of the piece *Trio for Two Musicians* is that it is playable by musicians with little or no previous experience of electro-acoustic music. Rehearsals for the work confirmed that performers were comfortable reading a form of notation where pitch is specified using frequency, where duration is specified using a vertical radio button and where the ensemble is coordinated by a graphic score that conducted the performance. Moreover performers were able to do this easily and perform it accurately. Moreover, the pitches specified were not in standard 12-tone equal temperament.

The performance configuration is an extended instrument system in which multiple performers share musical information across a network. The work explored new creative opportunities for an ensemble of live performers using polymeter, microtonal harmony, algorithmic DSP control and the spontaneous interaction with sampled sound, replayed and transformed.

The central motivation for developing *Trio for Two Musicians* came from two new works for community orchestra that I composed and had performed during the period of my candidature. The works in question were entitled *Money Box* (2006) and *The Wollongong Overture* (2004). The parts were written at a level appropriate to the musicianship of each player as the complexities of ensemble interaction in a large orchestra increase when it is made up of players with limited orchestral experience. This resulted in problems with ensemble intonation and synchronisation. Such problems can only be rectified when performers develop the musical coordination skills that come from listening to one another and from watching the conductor.

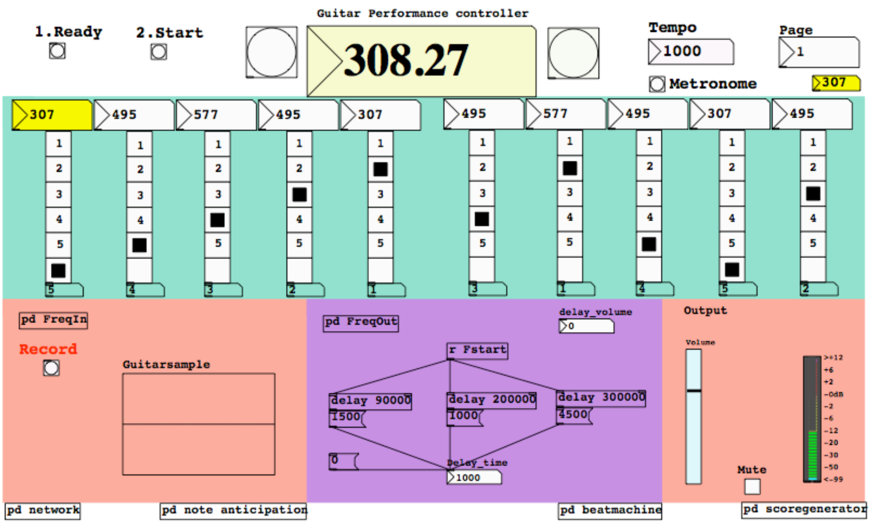
Musicians learn to adjust the timing and fine-tuning in an instant in much the same way that the computer does in *Trio for Two Musicians*. The computer is programmed to make such adjustments as it listens and responds to the individual players. However, the computer may also assist the players' intonation and synchronisation in ways that would not be possible for musicians in conventional ensembles. Moreover the computer along with the performers are equal contributors to the musical outcome.

As the central composition in my folio of creative works, *Trio for Two Musicians* provides the blueprint for new forms of ensemble communication.

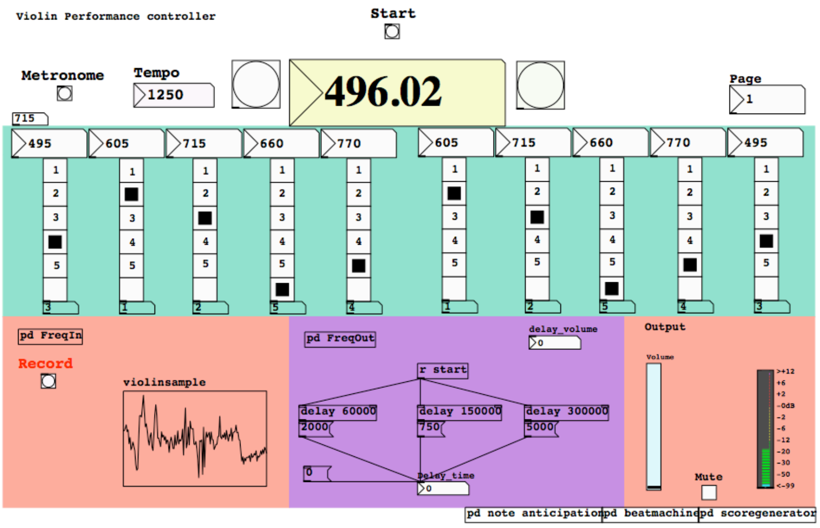
Appendix A – Performance Controllers

A.1 Screen 1 (Master)

The master performance controller contains all the score information and the controls necessary to initiate the performance. Each part of the controller is linked to sub-patches that are hidden from the view of the performer to facilitate all the parts being presented in one screen for ease of use.

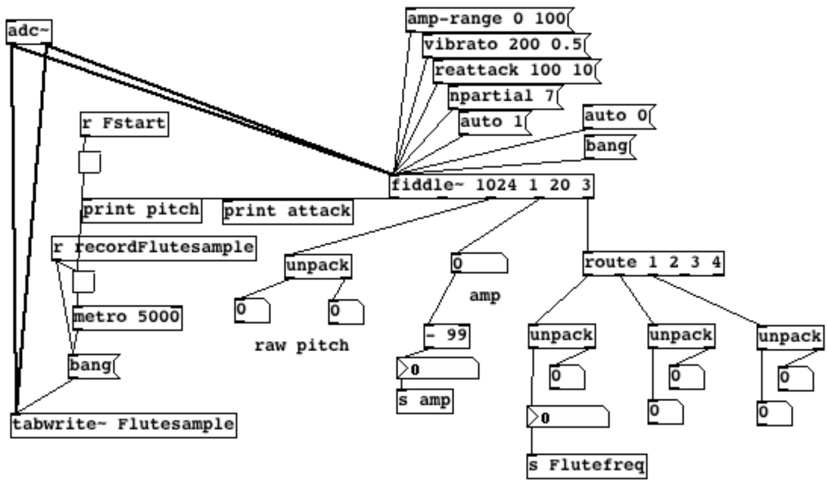


A.2 Screen 2 (Slave)



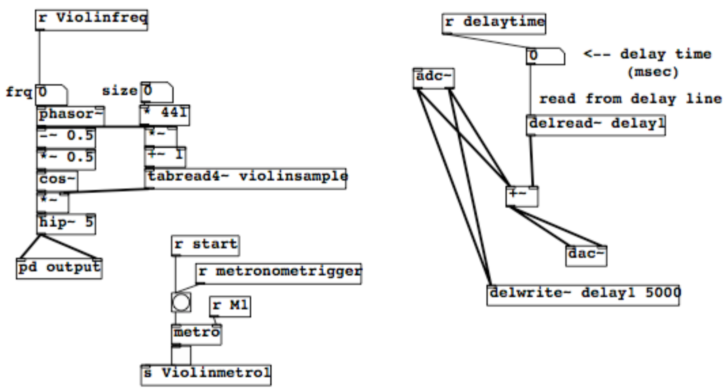
A.3 Pitch tracker (FreqIn - Master, Slave)

This is a sub-patch hidden from the view of the performer and is named FreqIn on the performance controller. It contains the command objects that sample the frequencies from the live audio input signal.



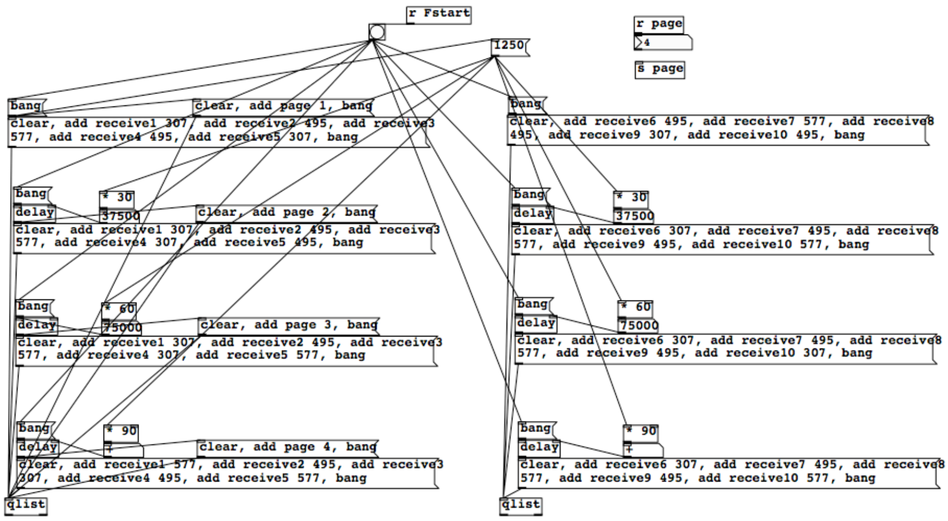
A.4 Looping (FreqOut - Master, Slave)

This sub-patch contains the command objects that loop the one-second audio sample. This loop is the ‘third voice’ described in chapter 3 of the thesis and is shown here being sent to the audio output (pd output) of the computer. It also contains the command objects for the delay effect added to the looped audio signal.

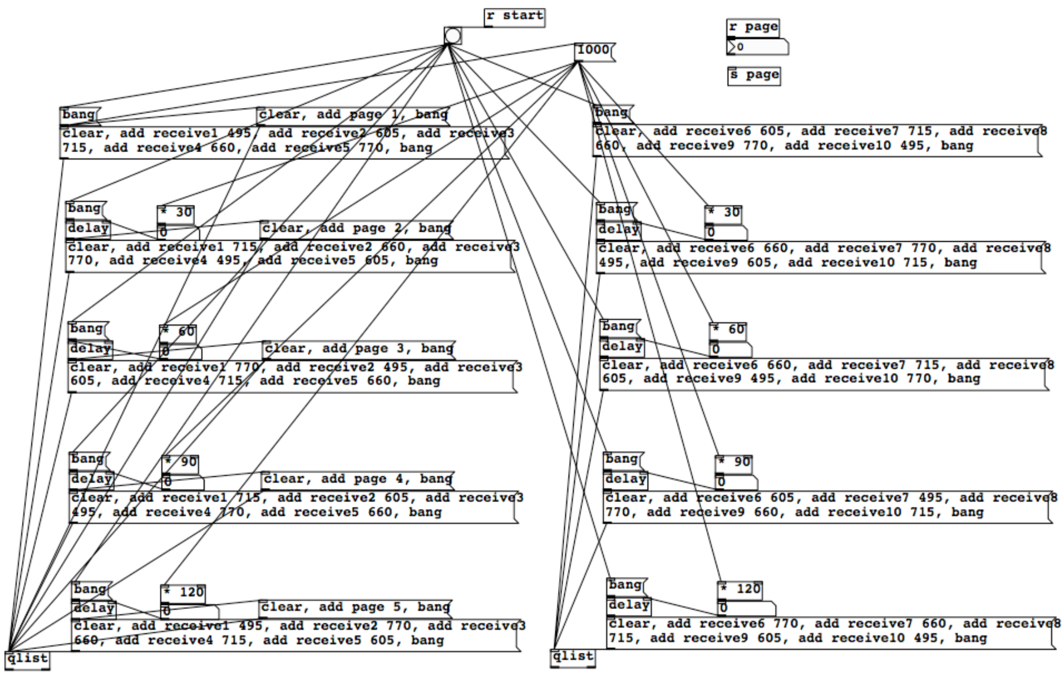


A.5 Score Generator (Master)

This sub-patch contains the command objects that present the list of frequencies on the performance controller display for the performer to read. There are four pages for the master controller and five pages for the slave controller shown in A.6. The difference in the number of pages is due to the difference between the master tempo and the slave tempo.



A.6 Score Generator (Slave)



A.7 Pure Data Objects used in the Performance controller

cnv	Canvas
nbx	Number box
vradio	vertical radio button
bang	Output a bang message
vu	vu metre display
vsl	Vertical slider
tgl	toggle switch
text	Write text
msg	Message box
print	Print out messages.
pd	Define a subwindow.
canvas	Defined area for connecting objects
array	Table of numbers
send	Send a message to a named object.
recieve	Catch "sent" messages.
qlist	Message sequencer.
delay	Send a message after a delay time.
float	Store and recall a number.
trigger	Sequence and convert messages.
moses	Part a numeric streams.
dbtorms	Convert acoustical units.
*	Multiplication.
-	Subtraction.
metro	Sends bang messages at a timed rate
pack	Make compound messages.
unpack	Get elements of compound messages.
route	Route messages according to their first element
netsend	Connect to another computer via TCP.
netreceive	Opens a socket for TCP.
fiddle~	Estimates the pitch and amplitude of sound in.
adc~, dac~	Audio in/out.
delread~	Write to a delay line.
delwrite~	Read from a delay line.
tabread4~	Four-point interpolating table read.
tabwrite~	Non interpolation table read.
+~, -~, *~,	Arithmetic on audio signals.
cos~	Cosine.
phasor~	Sawtooth oscillator.
hip~	High pass filter.
inlet~	Add an inlet to a pd.
line~	Generate audio ramps.

Appendix B - Folio of Creative Works

B.1 Index

B.1.1 *Wandering Stars* **Tape composition** 1985 – John Spence. Created using the Driscoll Voltage Synthesizer

B.1.2 *On Suicide* **for soprano and computer** 2006 – Eisler and Brecht 1942. Arranged by John Spence and performed live at the Illawarra Performing Arts Centre by Karen Cummings soprano and John Spence on computer using the applications Reason and Logic Audio.

B.1.3 *SHarp Attack* **for harp and computer** 2004 – John Spence. Performed by Michelle Spence on Harp and John Spence on computer using the applications Reason and Logic Audio.

B.1.4 *Pure Melody* **for flute and computer** 2006 – John Spence. Performed by Sophie Ciufo on Flute and computer using PD

B.1.5 *Glimpses in 1 Second* **for Guitar and Computer** 2006 – John Spence. Performed by John Spence on guitar and computer.

B.1.6 *Polymetric Study* **for flute and Violin** 2009 – John Spence. Performed by Jane Aubourg on violin and Julia Corcoran on flute.

B.1.7 *Trio for Two Musicians* **for guitar and violin** 2010 – John Spence. Performed by John Spence on Guitar and Jane Aubourg on Violin.

B.2 (see CD)

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