WHEN LINES BECOME BITS: ENGAGING DIGITAL TECHNOLOGY TO PERFORM WORKS BY ALVIN LUCIER

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ABSTRACT

New music ensemble Decibel is a group of musicians, composers and improvisers who pursue music that combines acoustic and electronic instruments. In May 2010, they presented a concert of works by American composer Alvin Lucier (b1931), applying a range of new approaches to the reproduction of this important artists' works. Lucier has made clear that he sees technology as a tool, a means to an end [8, 122]. Different possibilities for his works - such as alternative instrumentation, lengths, and live or recorded versions of pieces - were suggested in many his scores. The adaption of certain analogue electronic components in the works using digital software and hardware has facilitated many of these suggestions. In addition, Lucier's compositions provide an opportunity to demonstrate how vital the performance of electronic sound generation and manipulation is when combined with live instruments. This is articulated in the consideration given to spatialisation of sound reproduction, the placement and assignment of performers to electronic sound generators and the use of software to facilitate performance requirements. Whilst Decibel may not be the first to attempt these adaptations and approaches, they have presented a number of Australian premieres of Lucier's work and have carefully documented the process of their realisation in this paper. The curatorial rationale, methodologies applied to the proof of concept and live performance of the works, as well as the results achieved are discussed.

1. INTRODUCTION

> *"Every room has its own melody, hiding there until you make it audible" [8, 92].*

Decibel formed in 2008 and the group is based at the Western Australian Academy of Performing Arts (WAAPA) at Edith Cowan University in Perth, where the majority of its members lecture in the composition and music technology departments.[1] The ensemble has a unique skill base. Directed by Cat Hope (alto flute, electronics, bass and composition), other members include Lindsay Vickery (clarinets, saxophones, Max/MSP programming, composition), Stuart James (piano, percussion, Max/MSP programming, Arduino, composition), Malcolm Riddoch (electronics, bass guitar, internet) as well as non-departmental members, WAAPA graduates Tristan Parr (cello, electric cello) and Aaron Wyatt (violin, viola). Whilst the ensemble aims to perform and encourage the composition of works by Western Australian, Australian and international composers, Decibel also perform what they call 'monograph' concerts – concerts that study the repertoire of one particular composer.

Their most recent monograph *Still and Moving Lines* presented a selection of music by American composer Alvin Lucier, a pioneer of music compositions that combine electronic and acoustically generated sounds. The concert featured a range of Australian premieres, and was curated to include a broad range of Lucier's compositional approaches. Original technologies employed by Lucier in his works were carefully considered and revised using digital technologies. This was primarily the use of digital audio interfaces enabling recording and sound manipulation, as well as Max/MSP programming environments and the use of Arduino[2] interactive boards.

2. CURATING THE PROGRAM

Lucier himself *divides* his practice into three distinct areas; works that explore the spatial characteristics of sound itself, works that explore the acoustic characteristics of natural and architectural spaces, and works that render the inaudible audible [8, 434]. Pieces

[1] More information on Decibel can be found at http://decibel.waapamusic.com including program notes and music from the Still and Moving Lines concert.
[2] Arduino is an open-source electronics prototyping platform based on flexible hardware and software.

for instruments with sine tones, contact microphones, found sound, unusual playback environments and mixed ensemble were chosen.

In the Decibel concert *SomAcoustica* (2009), two of Lucier's *Still and Moving Lines in Families of Hyperbolas* pieces (1973-74) were performed; No. 12 for two sine wave generators and violin, then No. 3 for two sine tone generators and flute. These pieces are some of Lucier's first to fully embrace sine waves as a musical sound source. This concert took place at the Callaway Auditorium at the University of Western Australia, an acoustical space that appropriately draws attention to the phasing relationships established between the sine waves and the instrumentalist. With minimal acoustical problems such as resonant frequencies, standing waves, comb filtering, and flutter echo [3, 261-319], venues such as the Callaway Auditorium are ideal for works that demand an intense and refined listening experience. To create the sine waves in these pieces we used two analogue sine tone generators, a simple Wien bridge Kikusui RC Audio Oscillator Model no. 418, and a Trio Audio Generator, AB-2202A. These were each manually tuned by ear against a reference sine tone generated using the Max/MSP software application. In this way the analogue sine tone generators were tuned accurately by reducing the frequency of beating created between the software and hardware oscillators; this overcame some of the inaccuracies that might otherwise have been created by tuning solely by the use of the rather inaccurate large dial on these tone generators, seen in Figure 1.

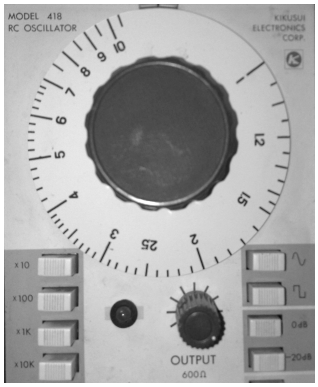

Figure 1: Kikusoi RC oscillator 418, showing the large dial.

Decibel are keen to debunk the idea of stereo as the default configuration for the majority of electronic playback, and the ensemble has explored this approach in each of their concerts by configuring powered monitors in the acoustic space in the same way acoustic instruments are. For a successful integration of electronic and acoustic timbre, each instrument – electronic or acoustic - requires a performer. This performer holds the ultimate responsibility for the character of the sound produced, which can be shaped by the final mechanism in projection, the speaker. For the Lucier pieces in *SomAcoustica,* the sine tones were played though powered Event Project Studio 8 monitors, one for each tone, situated either side of the performer. Each generator had its own performer/controller who tuned the tone, faded it in at the start and out at the end. The volume was set just under that of the violin and flute volume (played softly) in the auditorium to create the optimal acoustical beating. Lucier himself was very happy with the result, commenting on the recording we made of the concert by noting "I listened to the performances of Hyperbolas and found them beautiful" [9].

For the *Still and Moving Lines* concert, however, we decided to create all tones from our MacBook computers via associated sound cards, again amplified through the powered monitors. This way we could tune precisely and silently, making the change over between different works simpler and more precise. In fact, it was suggested by Lucier's publisher, Material Press, claiming Lucier himself preferred tones generated in Max/MSP to those on older sine tone generators [4]. Despite misgivings regarding the quality of digitally produced tones compared to those produced by analogue machines, both analogue and digital systems present advantages and disadvantages. Whilst analogue oscillators are often preferable in terms of their tone and character, they are prone to fluctuation in pitch due to thermal conditions affecting internal components including those integral to the VCO circuit. The frequencies of digital oscillators are not affected by these conditions. Further to this, analogue technology is also prone to a higher noise floor than digital equivalents due to random fluctuations in an electrical signal, a common characteristic of all electronic circuits. Digital systems present an advantage here since until a digitally generated signal is converted to analogue, it is not subject to the same degradation in signal quality. As a consequence, digital oscillators have a much improved signal-to-noise ratio. Whilst there is still a debate over the quality of digitally produced tones as compared to those produced by analogue machines, in the live situation the difference is surely negligible when a quality audio DA converter and balanced audio leads are employed.

Once it was decided to use computer generated sine tones, Decibel approached the entire *Still and Moving Lines* program using digital technologies to replace all analogue ones suggested or dictated in the scores. In addition to the production of sine tones this would also involve programming controllers, switchers, routing and light activation as well as rendering all recordings digitally.

3. DIGITAL RENDITIONS OF WORKS

Below follows a discussion of Decibel's approach to some of the works presented in the *Still and Moving Lines* concert, and a summary of the results. Extensive research was undertaken to determine concert

interpretations by other artists and ensembles in the performance of Lucier's works. This included conversations with clarinettist Anthony Burr, who together with cellist Charles Curtis released a double compact disc set of a selection of Lucier's works (Antiopic, ANS1002), and Australian ensembles Golden Fur and Ensemble Offspring who had performed other Lucier works in their programs. Decibel are by no means the first group to use digital technologies to perform Lucier works, yet the process of doing so remains undocumented, apart from a few examples discussed below. The *Still and Moving Lines* concert featured four Australian premieres: *Carbon Copies, Shelter, Hands* and *Directions of Sound from the Bridge*.

3.1. *In Memoriam Stuart Marshall* for bass clarinet and pure wave oscillator (1994).

In *Still and Moving Lines* this work was chosen as a continuation of territory explored in the earlier performances of *Still and Moving Lines in Families of Hyperbolas.* This work features only one tone of F sharp at 92.4 Hz throughout that the clarinettist performs with. This sine tone is produced by a simple MaxMSP patch through a single speaker, and the clarinet, like all acoustic instruments in this performance, was not amplified electronically. Using maxMSP to assist in the management of digital sound for Lucier's works is not new; in 2006 cellist Jeffery Kreiger devised a system for the performance for *Indian Summer* (1993) for electric cello, harmoniser and stereo playback [5]. The interest in *In Memoriam Stuart Marshall* lies in the acoustic phenomena of beating that occurs when the clarinet plays micro-tonally around the sine tone pitch. Beats are created as the clarinet pitch moves toward or away from the sine tone. Clarinet notes pitched above the tone will beat toward the speaker, and lower notes away from it. Lucier attempts to describe this motion with a diagram in the score, shown at Figure 2.

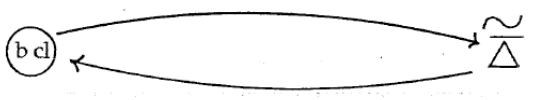

Figure 2: Lucier's drawing of the Bass Clarinet's spatial relationship to the speaker, taken from the score.

Whilst the score gives the option of producing the wave on a CD or DAT tape (Lucier's publisher sells these) Decibel decided to play tone live, with a performer fading the output level in and out as instructed on the score, sitting directly opposite the clarinettist, close to the speaker.

3.2. *Directions of Sounds from the Bridge* for stringed instrument, audio oscillator and sound-sensitive lights (1978).

This is another piece employing the sine tone, but here it is used primarily as a sound driver. A sine tone is sent to a transducer (a small, 7 cm speaker in this case) attached to the bridge of a cello. It is also the first piece by Lucier to explore the possibility of a sweeping tone, albeit very slowly and at a low volume level so as to keep the focus on the activity of the lights. The resultant vibration of the cello and its strings created by the tone activate lights situated around the cello in the concert space. They indicate, to some degree, the movement of the sound in and around the space as it exudes from the lone cello in the space. For the piece, the single performer was stationed at a computer, responsible for sending audio to the transducer in contact with the cello, and monitoring the volume levels captured by the microphones that activate the lights.

The American Other Minds ensemble performed this work at the Other Minds Music Festival in 1999 at Cowell Theater in San Francisco using flashlights. Diodes were used in the premiere performance of the work using a triggering mechanism devised by John Fullerman.

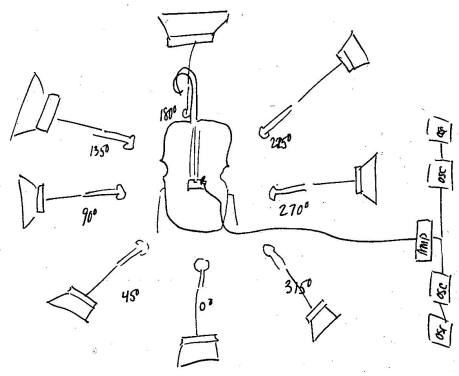

Figure 3: Lucier's own illustration of sound movement in *Directions of Sound From the Bridge* [8, 200].

Deciding on the final method for controlling the lights took some time and deliberation. Standalone circuit boards involving an electret transducer, op-amp resistors as used by Fullerman were tested initially. This option was initially preferred as it was thought that the simplistic ingenuity of a standalone circuit would also simplify the logistical requirements for setting up the piece in performance. By carefully adjusting the combinations of resistors and the op-amp used, it was possible to arrive at a response from the LED's that seemed to be effective for the requirements of the work. However, limitations became apparent when testing cheaper electret transducers in performance due to the electret having a high noise floor. On the other hand, a conventional condenser or capacitor microphone was becoming the preferred option due to both its extended dynamic range and low noise floor. This did present a problem as most condenser microphones require phantom power, and the microphones used in performance were most likely not going to be battery operable. A minimum of four microphones are required

in the performance, and it was difficult to justify the use of an additional four separate microphone preamps for sourcing the phantom power, it was decided that Arduino offered a simpler solution by allowing us to use the preamps and phantom available on the audio interfaces used throughout the performance. Furthermore, Arduino opened a huge scope of possibilities for both the control and the non-linear interpretation of input signals. Despite the 8-bit analog DA conversion via the digital PWM[1] outputs, Arduino had the ability to take a control signal from Max/MSP, and convert this to differences in voltage out of the digital PWM outputs, thus controlling how bright or dim a light might be [6, 127]. Out of the large selection of Arduino boards available, the Arduino Mega board was chosen due to the fact that it has 14 possible PWM outputs.

A Max/MSP patch mediated the interaction between sound and light, and Decibel engaged WAAPA honours student Kynan Tan to devise a system for the piece. The Max/MSP patch has two separate functions, the output of the sine tone to the audio transducer, and the reception of incoming audio signals from the microphones that are then outputted to the Arduino interfaced lights. To create the tone, a starting frequency is chosen, which is then accumulated by intervals of 2 Hz at one-second intervals. This rate of change provides a close to indistinguishable change in frequency. Lucier has noted that he chooses to create changes in acoustic resonance without obvious changes in the tone;

> *"I'm interested in the three-dimensional phenomenon, how sounds flow out from the instrument. I hear it in terms of weights. I get images of stone shapes or heavier-than-air sculptural shapes. And to make sure that the audience hears them clearly I have to sweep the oscillator frequency so slowly that they don't hear discrete changes of pitch. That would be confusing. So you just hear the weights change"[8, 202].*

Four microphones and lights are situated equidistantly around the cello. The microphones are used to capture the sound produced, which is then analysed to create envelope functions representative of sound intensity. The data from these four microphones is then remapped in Max/MSP to control the four LED lights via Arduino. The Max/MSP patch utilizes objects that average the strength of signals over 50 millisecond intervals, creating a series of values suitable for controlling the LED intensity. This mapping stage of the process allow the lights to undergo the "blinkings, dimmings and brightenings, partial and total blackouts and other sound-related visual phenomena" Lucier described in the score.

Further refinement was made to the patch to adjust the behaviour of the lights in response to varying levels of sound intensity. These adjustments involved remapping the output intensity to a non-linear response curve. This resulted in low values remaining black, mid-range values increasing more rapidly and all high values resulting in full strength light. Resulting light intensities could also be monitored on screen through a simple display in which four panels change from black to white depending on the data being sent to the lights. This allows for audio to visual inter-relationships such as phasing, blinking and dimming to be observed. An example of this display is shown in the still at Figure 4.

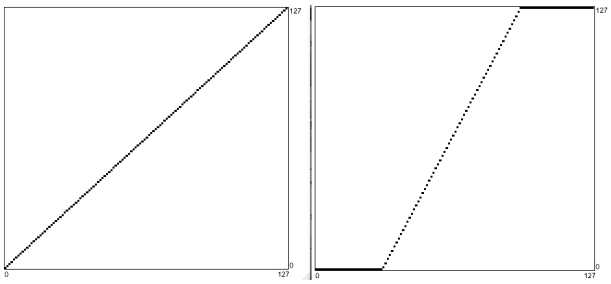

Figure 4: Two examples of response curves for LED intensity within Max/MSP; the one of the left showing the mapping for dimming and brightening, the one on the right maps a 'switching' effect.

The Max/MSP patch has several functions built in which makes it a very practical and useful alternative to analog electronics. The volume intensity from the microphones can be changed to make the light's response more or less sensitive. Resulting light intensities can also be monitored on screen through a simple display in which four panels will change from black to white depending on the data being sent to the lights. This allows phasing, blinking and dimming interaction between the lights to be observed, as shown in the still from the patch at Figure 5.

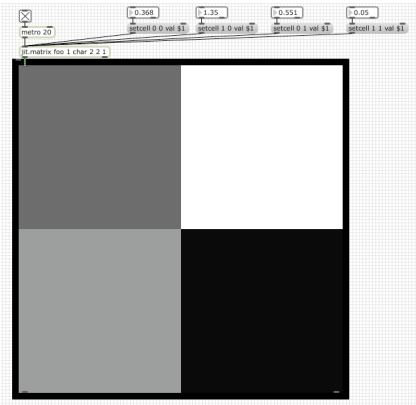

Figure 5: Max/MSP patch using Jitter to demonstrate different light intensities, black being off and white being on. Max/MSP patch by Kynan Tan.

[1] PWM stands for Pulse Width Modulation. Whilst microcontrollers can't output analogue voltage, they can generate a series of very rapid on-and-off pulses that can be filtered to give an average voltage.

While testing the piece, we found that it was important to note the fundamental frequencies of the cello (tuned to concert A440), as moving around these frequencies caused the most sympathetic vibration and clear harmonics. Other important factors were the distance of the microphones from the cello (around 3 meters was deemed the minimum to detect phasing), and the resonance of the space. With this in mind, there were several frequencies that stood out as being more visually interesting to sweep near. 130 Hz is the fundamental of a cello's C string and provided deep resonance, with another loud peak of activity at 160 Hz. The area around 230 Hz was very quiet, with a crescendo in volume between 330 and 370 Hz. The frequency range of 750-800 Hz provided a strong pattern of alternating lights when treated with a sine wave sweep rate of 1 Hz per second. Lower frequencies were significantly quieter than high frequencies, with those above 1000 Hz resulted in smaller variations at faster rates. Overall, a tone in the range of 200 to 600Hz rendered a sound that could be experienced from the rear of the auditorium.

Whilst LED's don't generally emit copious amounts of light, it was decided to use white super bright LED's, and then cover these with white opaque glass enclosures. By covering the LED with an enclosure, the light from the LED was dispersed, creating enough spread of visible light to be effective when observing the piece from an off-stage position. In the darkened auditorium, the lights lit the cello in the space, shading it according to the movement of the sound it projected.

3.3. ***Ever Present*** for flute, saxophone, piano and two pure wave oscillators (2002).

This work also used sine tones – but this time two notated sine tone parts in opposing sweeping motion, combined with three instruments of fixed description. Material Press forwarded the CD of the sine tones, but the was performed using two computers, each with its own powered speaker, either side of the performers. Again, this was to allow the tones to be performed by musicians. Another Max/MSP patch was created to facilitate the interpretation of the score, as seen in Figure 6. On the score, the tones are notated using a series of note heads with glissando indicators between them, indicating a more inclusive, musical inclination for the electronic instruments. This work has more complexities than the single instrument and tone pieces, due to the mix of electronic and acoustic instrument timbres produced, which can risk masking the beating effect if due care toward volume control is not undertaken. The acoustic instrumentalists may locate and interact with the tones as they do with each other, permitting the sine waves into the ensemble, blending amongst the colours of more traditional instruments.

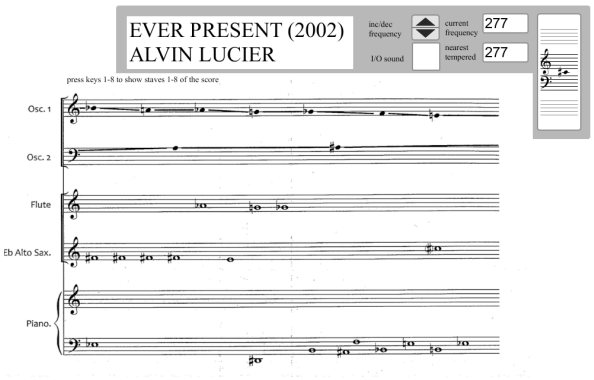

Figure 6: A page from the *Ever Present* score on a Max/MSP patch showing the notated sine tone parts (top two stave), and a simple sine tone player operated manully by a performer, relating pitch to noteheads and the tempered scale. Max/MSP patch by Lindsay Vickery.

3.4. ***Nothing Is Real (Strawberry Fields)*** for piano, amplified teapot, tape recorder and minature sound system (1990).

This delightful piece for piano and teapot playback is a delicate study on the resonant properties of the piano. The pianists live performance of Lucier's score is recorded and played back though the teapot which contains a small hand made 1-watt amplifier and a 5 cm speaker as described in the score. The teapot is 'performed' during playback; the lid is lifted up and down, as is the entire teapot lifted off the piano on two occasions. The teapot plays the piano recording through its very own physical body, re-interpreting it as the cello reiterated the tone sent to it in *Directions of Sound from the Bridge*. Finding the right teapot is important to achieve the right resonance from the piano, and after many visits to op shops, grandmothers and expensive china retailers, we settled on a thin walled ceramic teapot. Again a Max/MSP patch was constructed to automate the change over from recording the pianist in the first half of the piece, to playing back the recording though the teapot. This eradicates the wait for tape rewind.

3.5. ***I am Sitting in A Room*** for voice and electromagnetic tape (1969).

Whilst this is arguably the most iconic of Luciers works, this work has been presented primarily on recordings. The possibility of a live version of this work is suggested on the score itself where the line "versions that can be performed in real-time" is included. It also offers the opportunity to engage a guest with a distinctive voice to perform with Decibel, and so we engaged Peter Holland, a man with a voice familiar with most Western Australian's. Holland was a newsreader on the ABC seven o'clock news for over 30 years. His voice is instantly recognisable and his occupation as a broadcaster and communicator of information though the filter of the media made him ideal for the 'distinctive

voice' Lucier suggests for the piece. Holland read the text provided on the score and nothing else, as Lucier has expressed regret at his instruction to elaborate on the text in the score: "I also said in the finished score that other texts may be used. Perhaps that was a mistake because I don't want what goes into the space to be too poetic" [8, 92]. The score was edited for this performance however; the line after "I am sitting in a room" - namely, "a room different from the one you are in now" - was removed.

This is a more process driven work that the others featured in the *Still and Moving Lines* program. The decision to use a computer to record and play back Holland's distinctive recital of the text offered the opportunity for an efficient and compact setup to facilitate the process of both instantaneous and automated playback. Lucier states:

> *"I didn't choose to use tape, I had to, because in order to recycle sounds into a space, I had to have them accessible in some form. Tape then wasn't a medium in which to compose sounds, it was a conveyor, a means to record them and play them back one after another in chronological order"[8, 86].*

Utilising audio software to recreate this work is not necessarily a new or innovative idea. It has been performed using straightforward audio editing software by students at WAAPA, but also a Pure Data controlled version is well documented by Christopher Burns at the Centre for Computer Research in Music and Acoustics, at Stanford University, Stanford, CA, USA in 2000, running on a Linux workstation [2, 61].

Once again, Max/MSP software was deployed. The development of the patch presented some unique challenges, particularly as the instantaneous record and playback meant that the resultant effect of the acoustical space as an acoustical filter was accelerated. In order to slow this process of evolution, a feedback suppression stage was added to the patch. This consequently allowed for more flexibility in performance, and pre-empted any extreme build-up of frequencies that might inevitably result in reverberant acoustic spaces, especially those spaces with minimal acoustic treatment. The patch included the functionality employed for *Nothing is Real,* that is the eradication of any wait that would have been necessary if tape were used – the record/ rewind/playback time. In Lucier's recordings of this piece, the different takes are spliced together, allowing the takes to run smoothly into each other during playback. At the time this work was composed, a live performance would have involved a wait to rewind or splice. Thus the application of digital technology has made both *I am Sitting in a Room* and *Nothing is Real* a very adaptable and realistic live performance proposition.

3.6. *Shelter* for vibration pick ups, amplification system and enclosed space (1967).

This work provided a different set of challenges for the ensemble, as it requires the sounds outside the performance venue (the 'shelter' of the title) to be played inside it. The ensemble decided to create as well as find the sounds to be played back into the performance space, where two powered monitors were configured in the space, each one with its own microphone input, moderated by a performer at a digital audio workstation. Performers (saxophone, cello, piano, and a performer opening and closing doors) were situated in the neighboring green room adjacent to the auditorium and improvised freely. The work was placed at the start of the program, running as the audience entered the shelter, their activity mixed in with the improvising. Two C-Ducer contact condenser microphones were used as the vibration pick ups. These microphones have a phenomenal dynamic range (>155dB) and accompanying preamplifier which minimizes induced noise and interference. After considerable experimentation, the best listening point for sound though the walls was heard in the large doors that separate the performance space from a small anti room to which the green room was adjacent (the green room had a common wall with the auditorium). Another microphone was placed on a wall close to the entry for the audience, though this produced a considerably lower volume signal. During initial tests latency was placed on the playback to measure the volume of any acoustical leak into the performance space against the level in the speakers. This latency was not used in the performance, where the signal was played through Logic Pro software and re-processed using a multiband compressor. In this way, the extremities in audible dynamic range are reduced, allowing the audience to hear many of the audible subtleties with as much clarity and presence as some of the louder dynamics.

The auditorium structure acts an acoustical filter. By strategically placing contact microphones around the auditorium, it is possible to capture the sounds and the transmission of energy through the structure of the building.

3.7. *Carbon Copies* for saxophone, piano and cello (1989).

This piece calls for the coupling of instrumentalists and field recordings, though a process of recording, listening and imitative improvisation. It is a work rarely performed, perhaps due to its difficulty. The work asks the performers to copy their own field recordings exactly which can be challenging. The content of the field recordings was decided by the artists Each of the performers (cello, clarinet and piano) have their own field recordings played back though a stereo pair of speakers' – making 6 speakers on stage - and headphones. Each of the performers made their own

recording using a digital hand held recorder, rather than the tape recorders suggested in Lucier's original score. After recording, files were transferred into a ProTools session for a simple editing process of cleaning the start and end of the files, making them all the same length and comparative volume. During the performance, a separate performer controlled the play back alterations required for the field recordings, assisted by a Max/MSP patch that automated the changes between different output sends with a simple mouse click, shown at Figure 7. These changes are required for three playback stages of the piece;

1. Speaker playback only + performers listening;
2. Speaker and headphone playback + performers playing;
3. Headphone playback only + performers playing and
4. No playback + performers playing.

This patch made the switch over clean, fast and neat, allowing the audience and performers alike to focus on the interaction between the performers and their field recordings, which is the key to the piece.

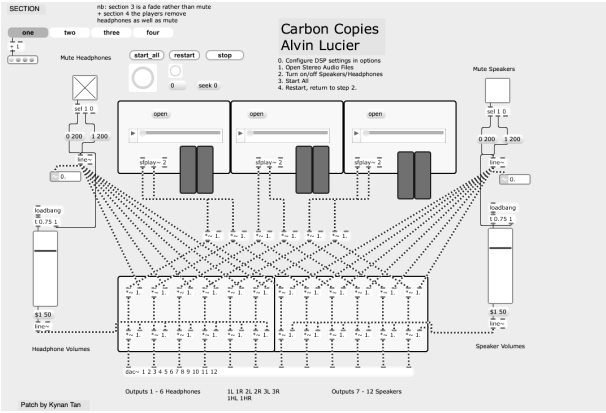

Figure 7: The GUI for the Max/MSP interface used in *Carbon Copies*. Max programming by Kynan Tan.

4. CONCLUSION

When Lucier began writing the *Still and Moving Lines in Families of Hyperbolas* pieces in the 1970s, technology was still regarded with suspicion by some [1, 227]. But Lucier has always regarded technology as a tool or instrument, and as part of contemporary life. It seems fitting that his tools are updated as contemporary life itself evolves. He spoke of electronic sounds such as sine waves as being devoid of personality [8, 228], inviting modification and alteration in order to facilitate their functionality as tools. Posing them as 'instruments' in an ensemble may prove contentious for some, but surely this only reflects the nature of music today, where electronic musical instruments make an important part of current music practice.

The digitisation of all electronically created and amplified sound in *Still and Moving Lines* created a unity in the presentation of a significant body of Lucier's work. It enabled a neat and efficient live performance of works that could have been otherwise cumbersome live, whilst maintaining the importance of the performer in the production of electronic sounds. Decibel's approach to amplification of the electronic and recorded ensured that each sound – electronic or acoustic – had its own voice in the performance space, and the space reflected a varied topography of sound from one piece to the next.

The qualities of Lucier's music are created with the very fundamental nature of sound, and the way sound interacts with a room, an instrument, a performer and an audience. This is a most pure form of music; where rhythms are generated by simple interactions of the sounds themselves, the melodies and colours come from the activity of the everyday, and textures are designed though regeneration. Lucier has described *I am sitting in a Room* as a piece closer in spirit to alchemy than to music, whose purpose it was to transform base metals into pure gold [7, 11]. Decibel's intention for *Still and Moving Lines* was to communicate this magic, and that Lucier's work reveals something hiding within the very stuff of music.

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