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Keynote Speaker:
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Music Review:
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Mark Webber
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All correspondence with authors should be sent directly to the authors.

General correspondence for ACMA should be sent to **info@acma.asn.au**

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KEYNOTE ADDRESS:

INTERACTION IN THE WORLD OF BEATS

Roger B. Dannenberg

Associate Research Professor
School of Computer Science and
School of Art
Carnegie Mellon University

ABSTRACT

Most art music eschews simple, visceral rhythms. A rock beat in electro-acoustic concert music is unheard of except as social commentary or irony. Research in our field has largely accepted this aesthetic direction. Computer accompaniment, conducting, improvising, and other interactive systems assume that tempo (if any) is meant to be manipulated expressively. As a consequence, computer music technology comes up lacking in the world of beats, characterized by a steady tempo, where rhythm and structure are tightly coupled. My vision is to create new interactive systems that accept the premise of beats and exploit that structure to the fullest. I will discuss how beats alter the very nature of musical interaction. I hope to engage student, amateur, and professional musicians at all levels in new conceptualizations of electro-acoustic music production and control. There is a tremendous potential for creative new directions and performance practices to emerge.

REFEREED PAPERS

ACTION A/V: AN IMPROVISATORY PROCESS FOR TRANSLATING MOVEMENT TO AN AUDIOVISUAL OUTCOME

Roger Alsop
School of Performing Arts
Victorian College of the Arts and Music
University of Melbourne

ABSTRACT

This paper discusses the computer based audio-visual improvising system *Action A/V* and the process of developing a series of improvised 'action audio-visual' works. It introduces the conceptual background to the process, discusses precedents and how *Action A/V* is differentiated form those precedents, and outlines how the system was made, and some testing of the system.

Action A/V is a process that builds on the idea of action painting, translating dynamic and ephemeral actions into an audio-visual event. It was designed to allow the processes of developing an artwork in one mode to create an artwork in a different mode.

In early tests and experiments, carried out at RMIT and discussed here, the movements of participants from a dance background generated the actions that were translated and then stored in a movie format.

The process through which these audio-visual events are triggered is designed to have similarities to the process of collaborative improvisation, in that the sounds and screen the improviser are interacting with are to some extent predicable and learnable by the participant. This allows participants to improvise with sonic and visual events in much the same way as they might improvise with another participant, creating a complementary interaction between themselves and the computer-based output.

1. INTRODUCTION

The term '*Action A/V'* harks from the process of 'action painting', made famous by Jackson Pollock, as shown in Hans Namuth's film *Jackson Pollock* [8]. In this film the direct relationship between Pollock's movement and the simultaneous creation of an image is seen to great effect.

Namuth's film, and the many photographs he took of Pollock in the act of painting, show the great mastery Pollock had of his technique and his ability to exercise it expressively [6]. This technical mastery allowed a unique expression to occur, one that caused a re-consideration of a painting from being a finished, representative, work to one that depicted the artist's process as being a major part of the work; a process where the canvas becomes "a space in which to … "express" an object, actual or imagined. What was to go on the canvas was not a picture but an event." [12]

This 'abstract expressionism', a term that followed on from and subsumed the term 'action painting' and is often ascribed to Pollock's work, was also ascribed to dancer/choreographer Martha Graham, a contemporary of Pollock [10]. Graham's work was intensely introspective, being based on, expressing, and being mediated by, the author's often-immediate internal, personal, and subjective, experience. In the case of Pollock and Graham this expression could not be given voice through literal forms or reification, instead they took an abstract form, requiring and allowing shape and movement to be the expressive tools of their intentions.

The obvious differences between Pollock's and Graham's work is that one is concrete and static, and the other ephemeral and dynamic. However, when viewing Namuth's film it is possible to see Pollock's movement in a similar way to that in which one might view a talented dancer; his gestures demonstrating great control, focus and intention, similar to that of a quality dancer. When viewing Pollock's movements it can be seen that the canvas becomes "an arena in [or on] which to act" [12], much like space is the arena in which a dancer acts. The canvas takes and documents Pollock's dynamic actions, translating them into colours and shapes on the canvas, therefore making them static and concrete. 'Action A/V' expands on this concept and process, creating a dynamic, temporal, but not ephemeral, audio-visual work, through concretizing the ephemeral actions of a participant.

2. PRECEDENTS TO *ACTIONA/V* AND ITS PROCESS

A great deal of work has been done in the area of mapping action to sound and visuals, the plethora of books, web pages, and journal articles dedicated to the topic attests to this. A comprehensive listing of writings on the topic up to 2004 can be found at *Interactive Systems and Instrument Design* in the sub heading *Dance Technology* [21]; a listing of practitioners and software can be found at *Dance Technology* [19]. While this site's focus is in the area of music, discussions include haptics, neurology, meaning (and subsequent interpretation) and facilitation through virtual computer based, and actual, instrument/interface making.

Local activity in the relationship between movement/dance and computer based interactive technologies can be seen locally in the work of Company in Space, Hellen Sky, Garth Paine, Critical Path, Chunky Move, autraLYSIS, and many more. And international activity includes the work of Troika Ranch, Nick Rothwell, Sarah Rubidge, and Johannes Birringer, and again, many more. Clearly these lists leave out too many very worthy practitioners, theoreticians, and academics. However, each of these artists, and many who have not been listed, contributes unique and idiosyncratic approaches, from both conceptual and technical points of view.

2.1.1. Two examples of the relationship between computers, action, and sound

There are a wide variety of roles that these practitioners take, and often the technology providers take a collaborative position, taking the role of enhancing the performance through their technological skills and the conceptual frames, paradigms, and processes that they bring to whatever project they are involved in.

Two examples of the relationships between artists engaged in computer based technologies collaborating with artists engaged in the more traditional areas of performance arts are: Nick Rothwell's work on *the Quartet Project*, and the relationships between Frieder Weiss and the dance company Chunky Move in the work *Mortal Engine*.

In *the Quartet Project* Nick Rothwell [13] worked with the Australian based media designer Margie Medlin, director of the work, and other sound, music, dance and media artists and programmers to produce a work "Informed by new scientific research in the field of physiology, this multi-media event is the culmination of several years collaborative research. [It investigated] the kineasthetics of music: determining movements which produce sounds, which in turn produce new choreographies." The project incorporated "Specialists from dance, music, biomedical and computational science, 3D animation and motion control" [13] .

When discussing the project, Rothwell [1, 14] outlined the way in which each of the four elements in the quartet influenced and interacted with each other, forming feedback between the different elements and performers, and potentially forming a complementary forward feed through the influence of the technology on the potential decisions of the musicians, dancers and virtual/robotic elements in the work.

The performance work *Mortal Engine* has two distinct sections, one, which is primarily oriented towards dance and projected images, followed by the other, which is oriented towards sound/music and visuals. In this piece, as in its predecessor Glow, choreographer and artistic director of Chunky Move Gideon Obarzanek, considered using video as a substitute for standard theatre lighting, and developed this idea to the point where the video became as much a part of, and agent in, the choreography as the movements of the dancer.

It was described as having "no pre-rendered video, light or laser images and the music is similarly generated by movement. Pre-composed phrases are triggered by the dancers' motions, or by the operator at the correct point in the performance. " [5]. Even so there is a great deal of interaction between the dancers and the other elements that is prescribed and rehearsed, with all events following a score, or procedure, that includes the interactive programming of Frieder Weiss.

Eyecon (© Freider Weiss) was the programme used in *Mortal Engine*, its "main use has been to facilitate interactive performances and installations in which the motion of human bodies is used to trigger or control various other media (music, sounds, photos, films, lighting changes, etc.)" [22].

In both cases the software designers developed systems that were both idiosyncratic to the designer or individualized to the project. Rothwell's approach was to design a system specific to and reacting to the outcomes required by the project. This was done in close collaboration with the director and the other participants, developing the artistic work and the tools with which to make it simultaneously.

Weiss, on the other hand, provided a pre-developed system through which Obarzanek could develop his work. In this situation Obarzanek was reacting to the technology available to him, in much the same way as a composer of instrumental music reacts to the instruments available to represent his or her ideas.

In discussio with the author, a dancer who performed in both *Mortal Engine* and *the Quartet Project* found that working with Weiss's program was more predictable than Rothwell's, resulting in a performance in which they could focus on their aspect of the performance more easily.

In these the relationship between the technological output and the performers was to create a cohesive whole, in which all elements coalesce to form a single work containing each of the disparate elements.

2.1.2. Differentiating ACTIONA/V from previous approaches to integrating movement and technology.

The majority of performance situations that integrate movement, music and vision through computer technology follow similar paradigms to the integration of those elements without the use of computer technologies. In these cases the relationship between the various elements, lighting, sound and projections, are complementary at best, but very often given a supporting role to the choreography and subsequently the dancer(s) on stage, which is the paradigm that the dancer mentioned above, and which most other performers feel most comfortable with. In both *the Quartet Project* and *Mortal Engine* the role of the technician was in creating content that was complementary, or possibly the main focus of the work.

For much of the work of the practitioners considered above, their roles and contributions fit within this traditional, well known, and useful paradigm. This particular paradigm is based on the very normal desire in the performance maker and their audience to place primacy on the human element of the performance. As humans we are naturally inclined to give our attention to that element within any communication process, and performance is no different.

ActionA/V differentiates from this approach in that its purpose is not to create work that unifies or coheres disparate elements. Instead it considers the process used by the action painters, one in which their movement was recorded and interpreted as a different artwork, to be viewed without and separate from the human element involved in its creation. Here, as the participants interact with the audio/visual interpretation of their movements, that interpretation is captured in the form of a movie, thus creating a work in a different format.

3. PROCESSES AND SYSTEM DESIGN

When developing computer based interactive systems, particularly those in which untrained participants are involved as the causative agent, it is important to create a balance between the interaction between the participant and the system being so predictable that the participants lose interest, and the converse, where participants lose interest because they do not experience a satisfactory sense of agency in the work.

When developing this software the original aim was to create an interactive system similar to that of a dancer improvising movement with another dancer, where there is an assumption that any interaction will be reciprocated in a recognizable way.

The intention was to develop a system that facilitates the translation of movement into sonic and visual elements. The system should create real time interaction between the movements of a participant and the audio/visual results of their movement that is recognizable, without being too prescriptive or overly predictable for the participant. The goal was to create a system that allows for a similar kind of interaction that one may have with another person, therefore having a fairly high degree of predictability, as well as a degree of novelty.

To facilitate this, an interactive environment using a stationary camera to gather data was created. For the original experiments and tests a studio space in the School of Creative Media, RMIT, that contained a video projector, screen and sound system was used. It was possible to darken the studio space sufficiently to illuminate only the performance area, which was, at the farthest point from the camera, approximately 3 meters wide by 2.5 meters high. The system was tested with four people who interacted with the system either as a pair or individually. When the participants were interacting with the image on screen their own image was not seen.

When moving in the performance area the actions of the participants created a change in an image on a screen. If there is no movement registered by the camera the screen showed black, but any movement triggered an image to be presented. These images were made from the primitive shapes, each of which could be represented as an outline, or solid three-dimensional object. These shapes could then be altered, from the participants' perspective, using processes described below.

The original software for this system was designed and implemented using Max/MSP/Jitter 4.6, in subsequent versions this was updated to Max5. The video camera used was an Apple iSight video camera connected to a MacBookPro via Firewire. Subsequent versions of ActionA/V do not require similarly controlled environments to those described above, but the less controlled the environment the less control the artist has in creating the audio-visual work as the possible interference from the environment will affect the outcomes.

3.1. Physical system

The video camera tracked movement in the performance space, and the resulting image was divided into twenty virtual quadrants. The aspects of the projected image that are influenced by movement in each of those quadrants are listed in Table 1, which also describes the attributes affected by movement in each of the twenty quadrants. The greater the amount of movement in a particular quadrant the more that aspect of the projected image was affected.

The proximity of the participant to the camera is important. As the participant moves further away from the tracking camera, the degree of movement in each quadrant must increase in order to have influence, and the possibility of movements being registered over more than one quadrant decreases. This means that the participant can exert more subtle control over the shapes and sound by their proximity to the camera. If the participant is closer to the camera, movements are registered over more quadrants, and less movement is required to influence the image, this offers an opportunity for very subtle and fine movements to be used. If the participant is further from the camera larger and grosser movements are required to generate an influence upon the projected image.

Figure 9 shows a dancer, in this case Brett Daffy, close to the camera and indicates the quadrants his position is affecting. Here the participant would be influencing: the image rotation on the z and y-axes, to a greater degree than the rotation on the x-axis, the lighting position and the camera angle x-axis as there is more action in those quadrants. Other aspects of the image, such as Camera angles 2 and 3, the Dimension value and the Blur amount, would not be influenced; the primitive image would also be changing.

Figure 10 shows the screen image corresponding to Daffy's position shown in Figure 9. This image is the combined result of many preceding motions of the participant, and therefore relates to many different influences, such as the participant having just moved rapidly through quadrants 3, 8 and 13, and is part of a continually evolving, dynamic process. The image as seen by Daffy was in colour, comprising of blue, purple and green hues. Figure 11 shows movement in fewer quadrants than in Figure 9, due to Daffy being further from the camera.

3.2. Software System

As mentioned earlier, the software system used to create the system was the Max environment, and all objects are from those standard libraries. This allowed rapid development in an environment that allows a somewhat organic approach, with the capacity to experiment with different conceptual strands with an overall framework. The software has four basic areas, *Video capture*, *Sound generation*, *Video generation*, and *Output recording*. Each of these has sub-systems pertaining to their specific functions.

3.2.1. Video capture

Video capture converts the image of the performance space and all activity within it to a grayscale image in real-time, splits that image into 20 equally sized quadrants, and each of these affect different aspects of the image created in Video generation (see Table 1).

A temporal differentiating process measures the activity in each quadrant. Figure 1 shows these steps in a sub-system of *Video capture*. A similar sub-system was used for recognizing motion in each of the 20 quadrants.

Figure 2 shows the matrix used to parse the information from the Motion recognition system and then supply it to the *Video generation* system. Here the first five "p" objects, marked row1, influence the rotation of the image on the x axis, the position of the light source on the x axis, how the image is perturbed, the position of the light source on the y axis, and the rotation of the image on the y axis, row2, row3 and row4 follow in a similar way, with each of the "p" objects relating to the aspect of the image outlined within the object.

The information regarding degrees of motion is fed to the related aspects of *Video generation* from each of these sub-systems.

3.2.2. Video generation

The process of creating the videos was based on altering seven primitive shapes from within OpenGL 3D graphics: sphere, torus, cylinder, opencylinder, cube, opencube, plane, and circle. These shapes are selected by the participants' action as they moved in the quadrant relating to that aspect of the image. In earlier versions of the program the number of dimensions on the *x* plane could be dynamically altered through the action of the participant, as can the size of the inner circle of the torus shape, should that be the selected shape. This section of the video generation process is shown in Figure 3.

These shapes were then altered through the perturbation/distortion process outlined in Figure 4. Here the mathematical functions built into the Max program are used to dynamically alter the original, primitive, shape through the use of the basis function graphing process built into the Max environment. This allowed quite significant changes to the shape in accordance with the degree of activity in the quadrants relating to that shape.

The type of basis function used in the experiments was the transfer.sine function, as this requires less processing power than other basis functions, and resulted in more intuitively predictable outcomes for the participants. The basis scale, basis function time offset, and the basis function displacement operate together to influence the degree of distortion of the original shape.

In later versions of the program the movements of the participant could select theses shapes, however in the version used in the experiments at RMIT, the shapes used were sphere and torus.

The system for determining the virtual positions of the participants when viewing the virtual objects is shown in Figure 5.

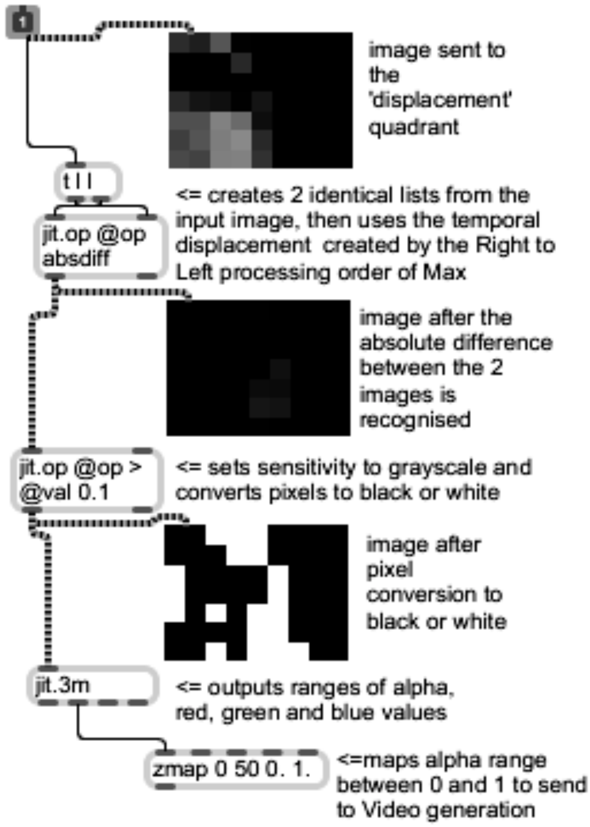

Figure 1: Motion recognition system

Using these three attributes to orient the image from the viewers' perspective, in effect, simply changes the image as seen on screen. However, what is does facilitate is a very subtle control of the perceived shape of the image, as miniscule changes to particular aspects of the image can be wrought through very subtle movement by the participant.

The image is then rendered using the drawing modes, as shown in Figure 6. The possible modes are: points, lines, line_strip, line_loop, triangles, tri_strip, tri_fan, quads, quad_strip, polygon, or tri_grid. As these different modes are applied, the sense of the shape alters dramatically, as for example, the spaces inside an outline are filled, or just the outline is shown. It is possible that the movements of the participant can alter these aspects dynamically, depending on the drawing mode selected, resulting in a mixture of filled in or un-filled in shapes being seen.

Finally colour is applied to the image, also shown in Figure 6, and this is done through the participant moving through the quadrants relating to the red, green and blue hues. The sense of shading, intensity, and colour is influenced by the blend mode selected, which creates more interesting effects than simply using the alpha channel to create transparency when rendering colours to the objects generated.

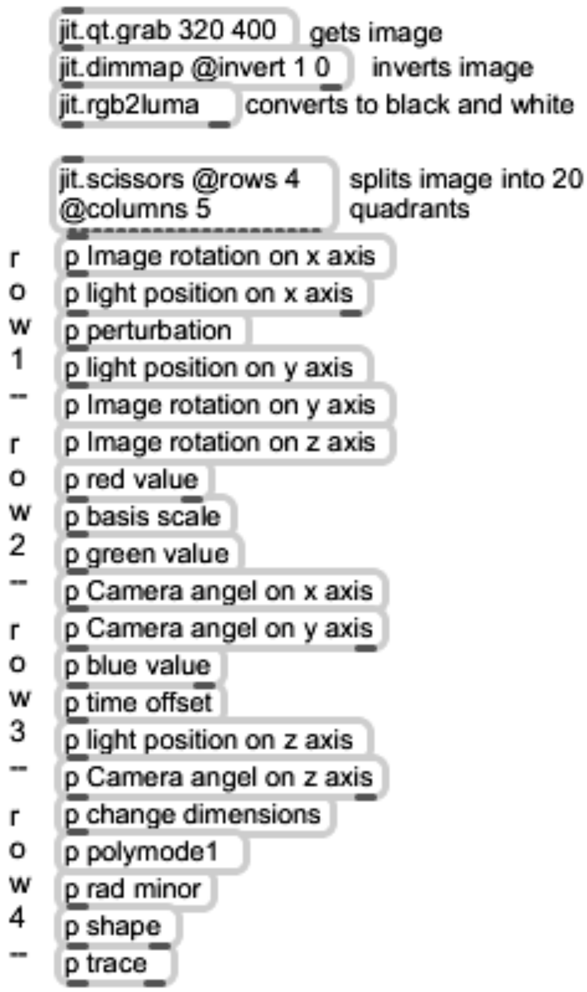

Figure 2: Motion capture parsing matrix

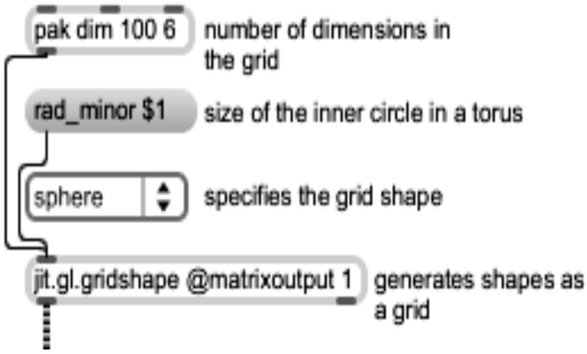

Figure 3: Process for creating simple shapes

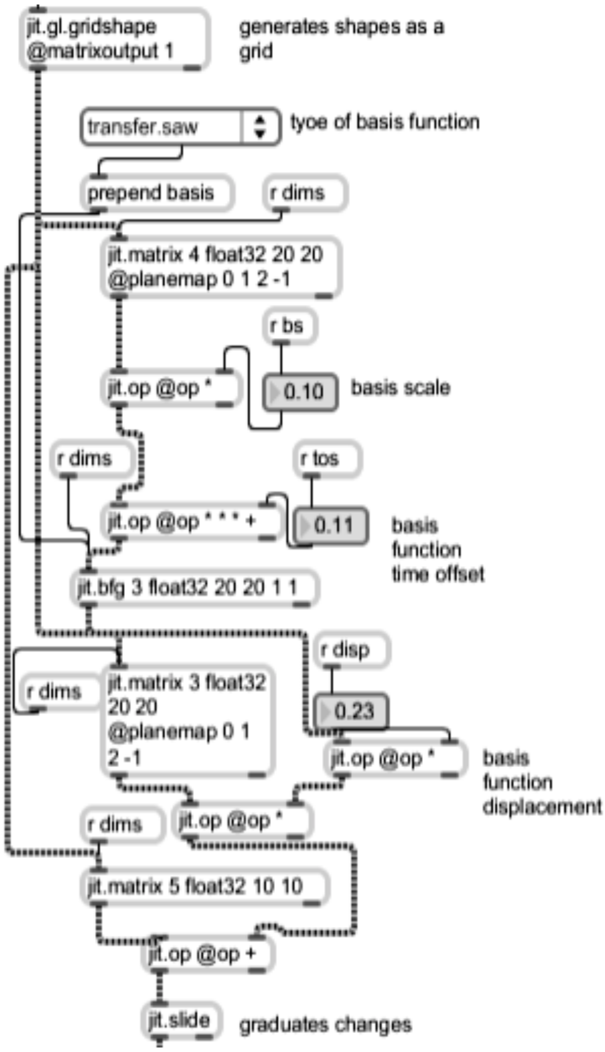

Figure 4: Process for perturbing the simple shape

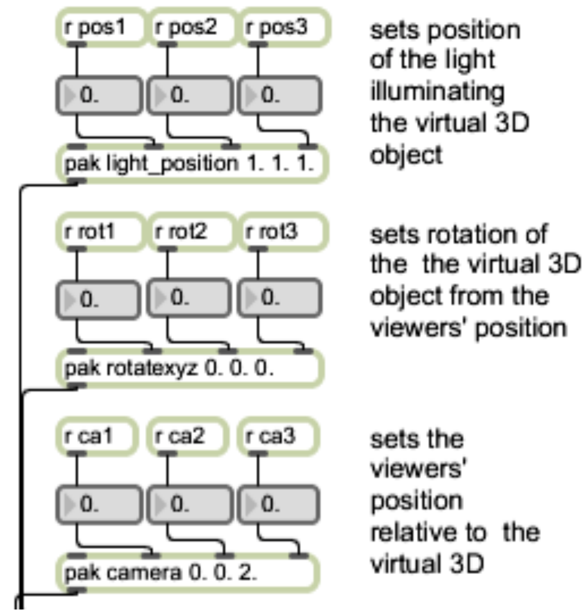

Figure 5: Process for setting the lighting position, rotation, and viewers' position relating to the virtual 3D object

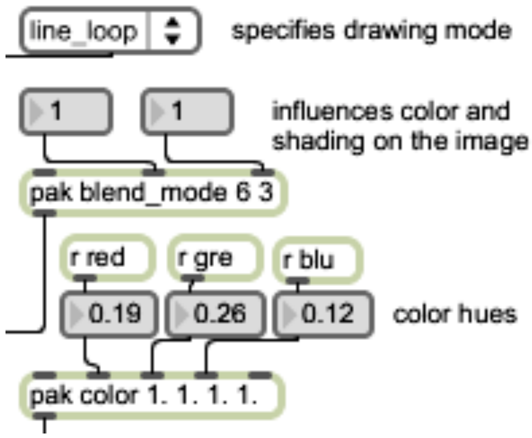

Figure 6: Process for adding colour to the virtual object.

3.2.3. Sound playback and dispersion

In the RMIT experiments, sound playback was done using five separate sample playback units that play continuously after being triggered at evenly spaced time intervals, shown in Figure 7 below. The result was a polyphonic texture built on a displacing, looping structure in which each part interacts with the other four to create a five-part canon; the sounds heard when the participants were interacting with the process are described in section 4, below. This system is also used in later versions of *ActionA/V*.

These five sound sources are routed through a matrix that gates the sound signal and specifies which sounds will be played through a stereo output. Each sample player is allocated to a specific input on the matrix which can then be output either of the stereo outputs. The output of each sample player is selected through the movements in ten of the quadrants around the periphery of the performance area.

While the samples are continuously looping, the motion detected in the performance space, and thus the mover in the space, decides which and when the sounds are heard via the gating/matrix process by selecting the sounds that pass through the gate. This allows the possibility of melodic and polyphonic outcomes, with each of the five possible sounds being triggered by movement in the performance space.

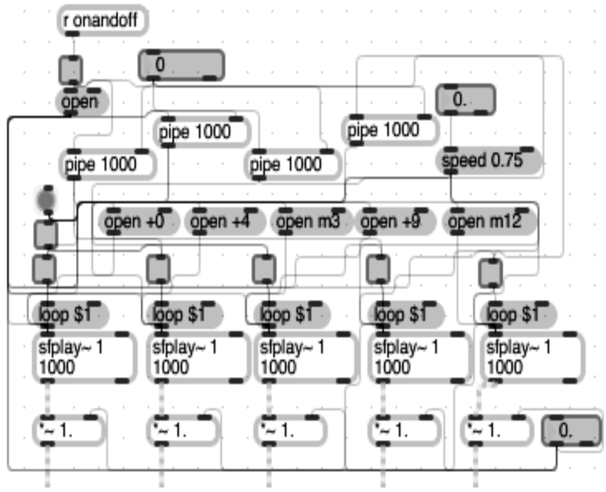

Figure 7: Sound file playback

The pitch intervals use in the RMIT experiment comprised a major pentatonic scale, with the tonic repeated octave higher. This choice of intervals allowed an outcome that is inherently melodically and polyphonically pleasing to the ear, within the typical Western musical traditions.

While the global inter-onset time between sounds was set, as were the durations of each sound, the actual effect was the creation of a participant controlled melody/polyphony that influenced the improvisation that generated the works.

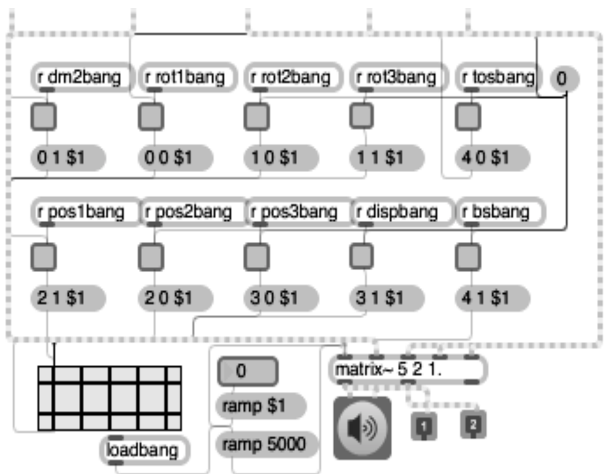

Figure 8: Sound dispersion process

3.2.4. Output recording.

The video and audio output generated by the participants at RMIT was recorded as .jpeg files. A video of the performers as they interacted with the program was also taken. This allowed the reinterpretation of their actions to create other works built from the program that they interacted with, or from developments of that program.

4. PARTICIPATION IN THE RMIT TESTS

Three dancers of various experience, focus and skill, and one actor, whose practice has a movement focus, participated in the experiment and development of the work(s). This occurred in a studio over four, two to three hour, sessions. The were not given any direction, but could move within the performance space and could orient themselves to the motion-tracking camera and the screen that showed the results of their movements in real time as they wished.

These dancers were asked to improvise with the image seen on screen and the sound that they heard in much the same way that they would interact with another dancer in an improvisational setting, considering their interaction as they would if improvising with another dancer. They were then asked to interact with the sound and moving image in order to create images and sound that were pleasing to them, or that they feel have some artistic validity or merit. Therefore they were asked to create a work in a form other than dance through their dance-like and dance-informed actions.

When introduced to the project participants were given a very rough outline of the project, being told simply that their movements would be interpreted as sounds and abstract images on a screen. This ensured that the participants had a clear idea of their role and the potential outcomes of their interaction with the program when they arrived for the experiments. During the process the dancers could not see their bodies on screen, only the results of their actions. This was so that they were not overly distracted by images of themselves, instead giving their attention to what they saw as a result of their movements more than themselves.

The process for developing an understanding of how to interact was essentially heuristic, following the trajectory: discovering what the images would do when they moved, how they could control the images, and how they could interact with the images as if they were another agent. After about twenty minutes of improvising the participants felt that they could collaborate with the images, as if with partner in developing an improvised work, after which they began to see their role as creating an audio-visual work and being comfortable with that role and agency.

When the participants were improvising with the screen they would often be surprised at how long they had been interacting with the screen; in one case a participant assumed that they had been interacting for about 10 minutes when in fact they had been interacting for about 40 minutes.

4.1. Creative descisions in the original tests

The sound for the original tests was generated from two sources, a sound file comprised of a solo voice sourced from the Logic 8 (© Apple 2007) sound library titled *Religious Voice*, which was convolved with a recording the speech Ronald Reagan gave discussing the Challenger Space shuttle tragedy of 1986 [11] using SoundHack (© Tom Erbe). This resulted in a sound-scape that had reference to the human voice in both song and speech, but without direct denotative aspects of song or speech.

As mentioned earlier, it is possible to create a melody by triggering the different sounds through their movement in the performance space, thus creating a melodic outcome through their actions, just as they create a visual outcome through their actions.

The rhythmic structures within each of these two sounds provide an overall rhythmic counterpoint, the religious voice being melismatic, and Reagan's speech being clipped and segmented, but still maintaining a sonorous sound. In both cases Reagan and the religious singer made extensive use of intonational devices to influence emotional responses in the listener.

The quadrant-based paradigm is used as it is seen as making an interface similar to that of a musical instrument. A piano, for example, has up to 88 quadrants, the keys, and each causes a specific sound to occur when physically activated. All musical instruments provide similar interfaces that translate a physical gesture into a sonic gesture; some allow a greater degree of interaction and control between the physical action and the sonic result. Here it is possible for the participants to cause responses in any or many of the quadrants, much like a pianist can depress one key or many keys simultaneously by moving closer or further away from the tracking camera, and to actively influence the output of each quadrant by the degree of movement made in that quadrant.

It was important that participants be able to hear and see the program reacting to their movements in a predictable way, similar to the way that a piano reacts predictably. Conversely it was important that the participants were not bored by the results of their interaction by those results being too predictable.

While the participants were interacting with the system they did not see their own image, this meant that they were not distracted by any considerations of their own movement other that how it affected the screen image. This resulted in subtler and more refined movements that focused on developing the onscreen image and that reduced their focus on the physicality of their movement as their familiarity with the results of their actions developed.

When deciding what influences to be attached to each quadrant the shape of a person standing in the centre of performance space was considered, as seen in Figure 9. Here movement in the upper central column of quadrants influences the changes made to the image shape but not original primitive shape, the quadrants both sides of that central column influence the colour and virtual lighting position, and the external columns influence the position of the virtual viewer. The bottom row influences the shape of the primitive and how transitions in that shape occur, this means that primitive remains constant unless there is a deliberate desire by the mover to change it. The results of the movements seen in this image would include much change in the shape of the primitive and the orientation of the viewer to the shape, but little activity in the colours seen on screen.

It was important that when interacting with the system the participants saw their movements represented in an unfamiliar way, so that they did not revert to familiar styles or clichés similar to those they may use when interacting with another dancer as they were interacting with the screen image, and so that they saw their movements being represented in a very different medium.

4.1.1. Image decisions

The images generated through the actions of the participants bear no resemblance to their actions other than to reflect the gestures as documented in the movies made. This has a similarity to the process of the action painters, with their actions being recorded in the still images that they created.

It was also important to ensure that there was as little as possible self-consciousness in the participants in the development of the *ActionA/V* documents. When dancers are developing their skills they are required to develop an awareness of their position in space, and in relation to other dancers around them, and to develop a sense of the quality of their movements within the various styles of dance. This consciousness often pervades their intuitive movements regardless of immediate context and purpose and can result in the unintentional use of clichés.

By removing the image of themselves from their immediate interaction, it was thought that the participants would possibly reduce their automatic use of and reliance on the tropes, conventions and clichés often apparent as a result of extensive training. It was also important that the participants consider the output of their actions as separate from themselves, much as the action painters considered their work on canvas as separate from their physical actions when developing the work. This was usually the case, with the participants quickly developing new libraries and styles of movement different from those they would normally use in an improvised movement setting, as they interacted with the sound and images generated from their movements

4.1.2. Audio decisions

The reason for convolving the two audio tracks in the initial tests discussed in 4.1 was to create an audio experience that could be thought of as complementary to the visual aspects of the work when the participants interacted with *ActionA/V*.

It was important that the participants sense a direct relationship and coherence between the sound and image. As the images on screen were flowing in their movement, unless the participant moved very suddenly and vigorously, it was decided that the sounds used should in some way reflect this. The movements of the participants influenced the playback of the sounds, as more active movement created more active melodic and polyphonic outcomes.

5. CONCLUSION

ActionA/V has developed from its initial driving concept, that of creating a system through which the processes of developing an artwork through the tools of one mode creates an artwork in a different mode, to be an interactive system that is both entertaining and interesting to the casual user and fulfills that initial idea.

Conversations with the participants in the RMIT experiments indicated that they were able to quickly understand the relationship between their actions and the movements seen on screen and the sounds heard, and to then develop a novel movement vocabulary that related directly to what they perceived as the vocabulary of the sound and images generated form their movements.

They also indicated that being involved in the project did cause them to reconsider their approach to movement and dance in an improvised and in more predetermined settings, in particular enjoying the ability to use very subtle movements to cause either subtle or gross outcomes, and vice versa.

Regarding the development of a system for translating processes across art forms, *ActionA/V* allows direct interaction between modes of expression. Here kinetic movement is seen to be creating a response, in a different medium, which has a direct relationship to that movement but is not in itself kinetic.

This method of translation allows for many other processes to be used in developing future works; any kind of motion or visual input can be used to generate the audiovisual material, and it is to be used for experiments and generating future works.

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1. Rotation on the *x* axis of the original image	2. Light position 1 relative to the position of the original image	3. Perturbation 1. Influencing the shape of the object	4. Light position 2 relative to the position of the original image	5. Rotation 2 on the *y* axis of the original image
6. Rotation 3 on the *z* axis of the original image	7. Red value	8. Perturbation 2. Influencing the shape of the object	9. Green value	10. Camera Angle 1 on the *x* axis relative to the position of the original image
11. Camera Angle 2 on the *x* axis relative to the position of the original image	12. Blue value	13. Perturbation 3. Influencing the shape of the object	14. Light position 3 relative to the position of the original image	15. Camera Angle 3 on the *z* axis relative to the position of the original image
16. Number of dimensions of the original image	17. Image type (alternating between outline or solid)	18. Radius minor (the size of the hole in the centre of the torus)	19. Shape primitive (sphere, cylinder, cube, or torus)	20. Blur amount, influencing the roughness of the image edges.

Table 1: Aspects of the video influenced by motion in the 20 quadrants

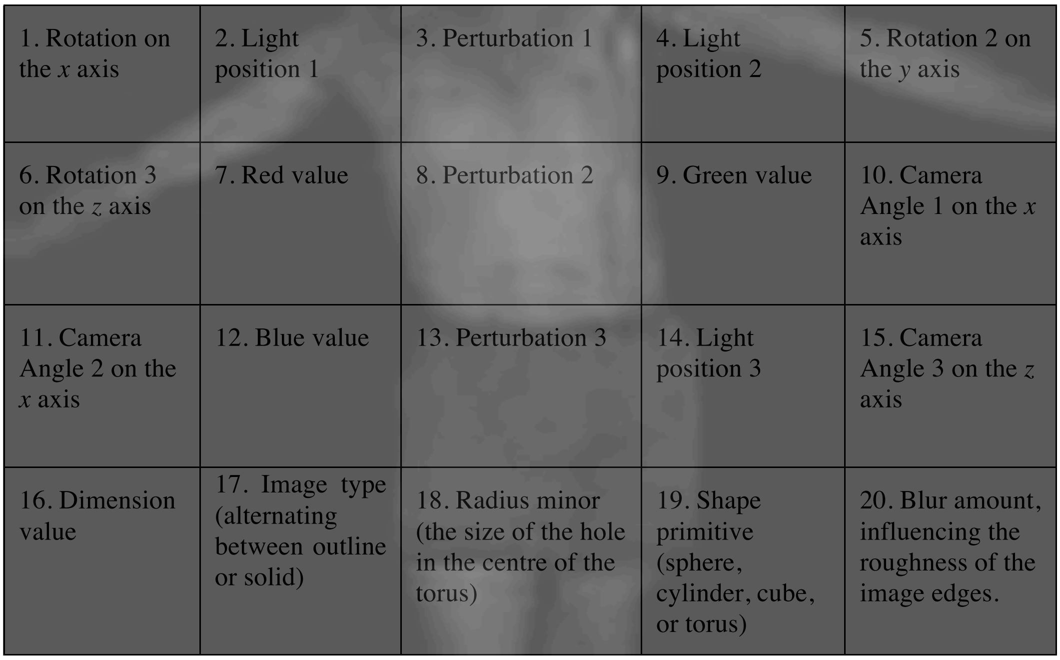

Figure 9: Movement in many quadrants

Figure 10: Resulting image from the movement in the quadrants shown above

1. Rotation on the *x* axis	2. Light position 1	3. Perturbation 1	4. Light position 2	5. Rotation 2 on the *y* axis
6. Rotation 3 on the *z* axis	7. Red value	8. Perturbation 2	9. Green value	10. Camera Angle 1 on the *x* axis
11. Camera Angle 2 on the *x* axis	12. Blue value	13. Perturbation 3	14. Light position 3	15. Camera Angle 3 on the *z* axis
16. Dimension value	17. Image type (alternating between outline or solid)	18. Radius minor (the size of the hole in the centre of the torus)	19. Shape primitive (sphere, cylinder, cube, or torus)	20. Blur amount, influencing the roughness of the image edges.

Figure 11: Movement in few quadrants due to distance from the camera

Anticipatory Timing in Algorithmic Rhythm Generation

Toby Gifford *Andrew R. Brown*

Queensland University of Technology
Victoria Park Rd, Kelvin Grove

1. Abstract

Generative music algorithms frequently operate by making musical decisions in a sequence, with each step of the sequence incorporating the local musical context in the decision process. Non-real-time algorithms often incorporate both past and future events in the context. Real-time algorithms, in contrast, generally include only past events since the future is unknown. However, even real-time agents *can* incorporate knowledge of their own future actions by utilising some form of planning. We outline a process for real-time rhythmic generation that incorporates a limited form of planning we call - *anticipatory timing* – that offers a worthwhile trade-off between musical coherence and efficiency. We give an example of a real-time generative agent - the Jambot - that utilises anticipatory timing for rhythmic generation. We describe its operation, and compare its output with and without anticipatory timing.

2. Introduction

This research has been conducted in the context of a larger research program investigating real-time machine listening and improvisation, culminating in a real-time machine improvisation agent, the Jambot[1]. In this paper we discuss the algorithm used by the Jambot for generating improvised percussive rhythms. This work extends previous work by the authors in the Ambidrum [3], a system for generating percussive rhythmic material with a specifiable degree of metric ambiguity. The primary differences are the inclusion of many more rhythmic heuristics, and an extended search technique that we are calling *anticipatory timing*.

Anticipatory timing is an extension of the typical approaches to searching used by generative algorithms that operate by optimising a musical fitness function at each step of a sequence of decisions. It involves extending the search to look a short way into the future, by searching over both the best note to play next, and the best time to play it.

In sections 3 and 4 we discuss existing approaches using contextual models for algorithmic music generation and analysis. The approaches are divided into two categories: rule-based systems and statistical models. The two categories are related, in that a rule-based system can be transformed into a statistical model and visa-versa. It is convenient for our purposes, however, to think in terms of rule-based systems because of their natural interpretation in terms of mathematical optimisation.

Considering algorithmic music generation as a problem in optimisation brings to the fore the question of efficient search techniques. Efficiency is a critical concern, even for non-real-time algorithms, because the size of the search space is vast due to the exponential growth of musical possibilities with the number of notes considered.

Rule-based systems have utilised a number of techniques to search the space of possible actions more efficiently than a naive brute force search. Many of these techniques involve performing the search in a step-by-step fashion, with the addition of some heuristics to 'prune' unlikely branches from the search tree.

The most extreme form of pruning is the class of so-called 'greedy' search algorithms [4], which hope to create an optimal sequence by making a series of locally optimal choices. Often the resulting sequence is far from globally optimal, however, the search is extremely fast.

Real-time systems are subject to much greater efficiency constraints than offline systems. Moreover, the nature of real-time systems demands some form of sequential processing. Consequently greedy search algorithms are very common in real-time improvisation systems.

The idea behind *anticipatory timing* is that it provides a mechanism to enhance greedy search to find better optima, with a tolerable increase in computational complexity. We suggest that anticipatory timing is particularly efficacious for the modelling of rhythm, which involves a mixture of pattern based modelling with a need to align the timing of elements of the pattern with both previous elements of the pattern, and with contextual cues such as the underlying metre.

In section 5 we describe a new generative model of rhythm that is incorporated into the Jambot. This model is a rule-based system that combines a number of rhythmic heuristics, including heuristics regarding the relation of the rhythm with the underlying metre, and heuristics that describe surface properties of the onset timings irrespective of the metre.

We give some examples of the Jambot's rhythm generation algorithm, both in solo and ensemble contexts. We compare the output with and without the use of anticipatory timing in the search, and conclude that the use of anticipatory timing enhances the musical coherence of its output.

[1] The term 'Jambot' has also been used by Andy Turner for an unrelated project that predates this work: http://www.andyware.com/.

The audio examples may be downloaded from http://dr.offig.com/research/papers/ACMC2010/AudioExamples.zip

3. Previous Work

This work extends previous work by the authors in the Ambidrum [3]. The Ambidrum is a system for generating percussive rhythmic material with a specifiable degree of metric ambiguity. It assumes that an underlying metre is supplied, and operates in real-time by applying heuristic rules relating the metric strength of the current beat to the emphasis of the note in the dimensions of velocity, duration and timbre. The generation of notes is performed at each beat (of a quantised time-line) by conducting an optimisation over the competing heuristics.

The Jambot's rhythm generation extends the Ambidrum by adding a number of other heuristics, including rhythmic properties that are not related to the metre, but reflect patterns of recurrence in the onset times.

The Ambidrum produces notes of a variety of durations, often longer than a single quantised beat. However, the underlying sequence that it uses is based on computing at regular time slices rather than generating one note after the duration of the previous has passed as is common in offline melody generation algorithms. In the Ambidrum process durations are implemented using a suppression technique; at each time slice the rules first check if the previous note's duration has finished, and if not the system takes no action.

The Ambidrum chooses its musical actions at each time-step by searching over the space of possible notes for the best note at that time. This type of process is known as a greedy algorithm (discussed further in section 3.4) because it opts for the best possible choice now, without any consideration of the future.

It is capable of producing simple rhythms that align closely to the metre, such as a standard rock beat. It is also capable of producing more complex rhythms that do not align with the metre, however, it is difficult to control these more complex rhythms.

The added heuristics in the Jambot's rhythm generation allow for much greater control of complex rhythms by mixing rules that target metric ambiguity with rules that target other forms of rhythmic coherence. By adding these extra constraints, complex rhythms can be produced by deliberate departures from the metre that nevertheless retain musical coherence.

3.1 Context Models

Most generative music algorithms, particularly real-time algorithms, operate in a sequential fashion. The steps in the sequence are most commonly either regular time intervals (for example as in a step sequencing drum machine) or notes (as is typical of common practice notation). At each step the algorithm must make a decision as to what (if any) musical action to take. Generally algorithms will incorporate the local musical context into their decision making process.

The context for algorithmic musical decisions is often taken to be the immediate history of musical material:

> The idea behind context models, which we are mostly interested in here, is that events in a musical piece can be predicted from the sequence of preceding events. [5]

The notion that musical events can be predicted from a history of previous events has led to a multitude of generative algorithms that can be categorised into two broad categories:

i. Rule-based systems - optimisation based approaches that combine heuristic rules with observed history to create a fitness function for the space of musical actions. The note to be played at each step is the note with the highest fitness.
ii. Statistical models - stochastic systems that provide a probability distribution for the space of musical actions. At each step the note to be played is drawn randomly from this distribution.

These two categories are related; a rule-based system can be transformed into a statistical model by reinterpreting the fitness function as a probability distribution, and a statistical model may be transformed into a rule-based optimisation system by choosing the maximum-likelyhood value at each step rather than making a random selection [6].

3.2 Rule-Based Systems

Rule-based systems for describing music operate by supplying a collection of heuristic properties that music is expected to obey. Historically, many rule-based systems have been intended for analysis rather than for generation [7, 8]. However, if systems for analysis are formalised sufficiently to afford computational implementation, then they may be used 'in reverse' as generative algorithms [9, 10].

A frequently cited example of a rule-based system for musical analysis is the Generative Theory of Tonal Music (GTTM) [11]. The GTTM supplies a collection of preference rules that well-formed music should conform to. Actually performing an analysis using the GTTM involves coming to a compromise between competing preference rules. Lerdahl & Jackendoff's model stops short of providing a computationally implementable scheme for deciding between competing rules.

> The reason [that we have not implemented our theory computationally] is that we have not completely characterized what happens when two preference rules come into conflict. Sometimes the outcome is a vague or ambiguous intuition ... We suggested above the possibility of quantifying rule strengths, so that the nature of a judgment in a conflicting situation could be determined numerically [11:54].

There have been various efforts to provide computational implementations of the GTTM or similar preference rule systems [12, 2]. These implementations consider the problem as a question of *optimisation*. In other words the correct analysis is found by searching through the space of possible analyses for the best analysis according to some weighted combination of the rules.

> In a given preference rule system, all possible analyses of a piece are considered. Following Lerdahl & Jackendoff, the set of "possible" analyses is defined by basic "well-formedness rules". Each preference rule then assigns a numerical score to each analysis ... The preferred analysis is the one with the highest score [2:15].

The task of implementing a computational version of the GTTM (or any rule-based system) as an optimisation problem is made difficult by vast number of possible analyses to be searched over for any given piece of music. To perform a naive search over all analyses in search of the optimal one is generally computationally intractable. There are, however, a number of search techniques that are substantially more efficient than the 'brute force' approach of exhaustive search.

A common approach to dealing with the combinatorial explosion of searching over all possible analyses is to perform a search in a sequential fashion, and to use some heuristics for 'pruning' unlikely branches of the search tree. Such approaches also seem more likely to provide a model for "the moment to moment course of processing as it unfolds during listening" [2:14]. One such approach is dynamic programming [13] which has found use in a number of algorithmic analysis and generation systems [14, 15, 16, 17, 2, 1].

Temperley has constructed a preference rule system similar to the GTTM called the Melisma model that affords computational implementation, and utilises dynamic programming to search for the 'best' analysis for a given piece of music.

> When the program searches for a globally optimal analysis based on the results of the local analyses, it must consider global analyses rather than simply choosing the best analysis for each segment in isolation ... Usually, even for a monophonic short melody, the number of possible local analyses may grow exponentially with the number of segments, and the size of the best-so-far analysis becomes extremely large. The Melisma system suppresses the explosion of analyses by properly pruning less significant analyses by dynamic programming. Temperley argues that, to some extent, this searching process reflects the human moment-to-moment cognitive process of revision, ambiguity and expectation when listening to music [12]

The Melisma system, although originally intended for computational analysis, has been 'reversed' to be a generative algorithm, the Melisma Stochastic Melody Generator [18], providing both an example of an analytic theory transformed into a generative process, and an example of a (deterministic) rule based system reinterpreted as a stochastic statistical model.

3.3 Statistical Models

There have been many statistical models of music generation, from simple mapping of mathematical functions such as periodic motion and random walks, to the use of more complex processes such as chaos theory and cellular automata. Some of the more musically successful statistical models have been probabilistic, often based on probability distributions derived from analysis of previously composed material. Recent coverage of probabilistic tendencies in music has been written by Huron [20] and Temperley [21]. Whilst these publications have focused on music analysis the use of these approaches for music generation is widely acknowledged, as described by Conklin:

> Analytic statistical models have an objective goal which is to assign high probability to new pieces in a style. These models can guide the generation process by evaluating candidate generations and ruling out those with low probabilities. The generation of music is thereby equated with the problem of sampling from a statistical model, or equivalently, exploring a search space with the statistical model used for evaluation. [10]

In a simplistic sense statistical models can be used to generate musical material at each step in sequence independently of context, however, as Conklin again acknowledges, it is also common and often more effective to use previous and concurrent note events to inform statistical processes of generation.

> The most prevalent type of statistical model encountered for music, both for analysis and synthesis, are models which assign probabilities to events conditioned only on earlier events in the sequence. [10]

The most common type of probabilistic model that uses past events as context are Markov models. These have been used for generation of computer music since Hiller and Isaacson's compositions in the late 1950s. Markov models are useful for sequential processes such as music because they describe the frequency of sequences of events, such as which rhythmic values follow each other.

Markov models, and many other statistical approaches, while they take account of past context, do not take account of future possibilities and therefore, we suggest miss an important opportunity to produce more optimal event selections. One challenge for extending statistical models to consider multiple future scenarios is the computational complexity of that can result.

3.4 Greedy Algorithms

Many real-time generative systems that utilise either Markov models or rule based operation operate via what is described as a greedy algorithm [4:370]. In an optimisation context a greedy algorithm is one which generates each step of the sequence by optimising locally. Generally greedy algorithms fail to find the global optima [21]. However, they are often used because they are much faster than exhaustive searches.

> The random walk method, while applicable for real- time music improvisation systems that require fast and immediate system response (Assayag et al., 1999; Pachet, 2002), is flawed for generating complete pieces because it is "greedy" and cannot guarantee that pieces with high overall probability will be produced. The method may generate high probability events but may at some stage find that subsequently only low probability events are possible, or equivalently, that the distribution at subsequent stages have high entropy [10].

Greedy algorithms represent the most extreme form of 'pruning' of the search tree; only the current action is searched over – which amounts to pruning *all* of the branches of the tree, leaving only the current node.

3.5 Existing Approaches to Rhythm Generation

There have been a number of approaches to the creation of rhythmic material in generative music research. We will describe some of them here so as to assist with comparison with our anticipatory timing approach.

A number of projects simply utilise existing or fixed rhythmic material for their generative music and thus focus attention on the pitch and or harmonic generative processes. Such systems include the Continuator [22] which replays rhythms played into it, and computational creativity experiments by Pearce & Wiggins [23] that utilise human composed rhythmic material and vary the pitched material. In a more granular way systems such as Cope's EMI [24] re-use sampled rhythmic material and rhythmic structure rather than generating it from rules.

Generative rhythmic systems include those that use onset probabilities at each time slice as described by Temperley [20:30]. Oscillating Rhythms [25] is a generative music software systems that uses cyclic functions to achieve patterns of recurrence of various rhythmic dimensions (onset, velocity and timbre).

The OMax system [5] uses a predictive coding structure trained on a database of rhythmic features, including duration, to decide on the next most likely note. OMax relies on time based sequencing using a greedy algorithm, however, it just uses probabilities of the current temporal location and does not employ any look ahead [5].

Collins [1] uses dynamic programming for his offline music generation algorithm. He also provides a greedy online version as an option for faster calculation.

4. Anticipatory Timing

4.1 Definition of Anticipatory Timing

To incorporate planning by naively searching over even a short number of future actions is computationally intractable. Even for offline systems this is not feasible, so smarter approaches to searching, such as dynamic programming, must be employed. For real-time systems such as we are concerned with computational efficiency is a strong constraint, and even full dynamic programming may be too expensive, so that greedy online variants of dynamic programming are sometimes used [1].

We propose *anticipatory timing* as a computationally tractable means of improving upon greedy algorithms. Anticipatory timing is an extension of greedy optimisation to include some level of anticipation in the timing of the next action. This involves searching both over possible actions *and possible times* for the next action.

At each step of the optimisation, the fitness function is calculated for each possible action, and recalculated again at each time slice (for a short window of the future). This calculation is done with the constraint that only one action is considered. If the highest overall value for the optimisation occurred at the current time slice, then that action is taken. Otherwise no action is taken at the current time slice.

If the algorithm anticipates that the best time for action is a few steps into the future then it does nothing at the current time slice. Supposing that nothing else changes (in the environment for example) then at that the future time the action is likely to be taken. However, if in the meantime something unexpected has happened, then the algorithm (which is run at every time slice) may re-asses the situation and decide against taking action at this time. This is particularly important in a real-time improvisation context, because it allows for *planning without commitment,* so that the algorithm may be flexible to unexpected changes in the improvisation.

4.2 Interpretation as pruning the search tree

Anticipatory timing is similar to greedy optimisation in only planning a single action at a time, but allows for the possibility of adapting the timing of this event if required. At each step of the generation the optimisation routine examines future outcomes at each time slice until the next event, but not every possible outcome in the rhythmic space. This increases the computational demand linearly with the number of beats that it looks ahead. This compares favourably with the exponential increase of complexity in full search planning of actions ahead.

In terms of 'pruning' the search tree, anticipatory timing amounts to pruning down to just a single branch. This branch consists of a series of 'take-no-action' nodes and terminates when an action is decided upon. This means that the number of computations required overall is equal to the number required for searching over a single action multiplied by the number of time slices into the future that it looks.

4.3 Comparison with full search

An alternative to anticipatory timing would be to plan a number of notes in advance. Presuming that we have a fixed amount of computational power available, a quick computation demonstrates how much further into the future we can look using anticipatory timing, rather than searching over the entire tree.

Suppose, for purposes of demonstration, that there are 16 possible notes to consider at each time slice. Suppose further that the bar is divided into 16 semi-quaver time slices. Using anticipatory timing we look a full bar ahead: i.e., at each of the 16 time slices in the bar we search over 16 notes. Then the total computation involves searching over 16 x 16 = 256 notes.

On the other hand, consider attempting to plan some number of notes into the future considering all possible combinations. Each time slice we must search over 16 notes, and for each of these notes we must search over 16 notes at the next time slice, and so on. Then by the second time slice we must examine 16 x 16 = 256 notes.

So for the same computation budget, we can look ahead a full bar of 16 semiquavers with anticipatory timing, but can only look *one* semiquaver ahead if we attempt to search the entire tree. To look ahead the full bar for all possible notes would require searching over 16^16 notes, which is approximately the number of grains of sand in the earth [26].

5. Examples using the Jambot

5.1 The Jambot's Rhythm Generation

The Jambot operates in the paradigm of a rule-based context model as described in Section 3.2. In order to decide upon which musical actions to take the Jambot performs a collection of analyses of the recent musical context (which may consist solely of its own output, or may additionally include the actions of other members of an ensemble). The analyses used will be described below: they include measures of rhythmic density, syncopation, periodicity and metric alignment.

The Jambot has a target value for each analysis, and searches over a quantised set of candidate actions so as to move the music as closely as possible towards these target values. The target values themselves are improvisational parameters which may be set in real-time by a human interacting with the Jambot, or may be set by the Jambot using a higher order generative process. In the examples below we have used static values for the target values with the goal of achieving stable repetitive rhythmic patterns.

In the discussions above of rule-based systems we have used the term *heuristic* to denote a particular rule, with the implicit connotation that the rule be amenable to numerical implementation. In the case of the Jambot each heuristic consists of a particular analysis combined with a target value for that analysis. The analyses all report a single numerical value between 0 and 1. For example, the rhythmic density analysis reports on the fraction of beats that have an onset. The value of the heuristic is the absolute difference between the analysis and the target value. Using the density analysis as an example again, if the target value for the density was set to 0.5 (aiming for 50% of the beats to have onsets) and the density analysis reported 0.25 (only 25% of the beats have onsets), then the value of the density heuristic would be 0.25.

There are four groups of heuristics used which are described in more detail below. The different heuristics are combined into a single objective function simply by forming a weighted combination of the individual objective functions. The weights used then also become improvisational parameters which may be set by hand or generatively.

5.1.1 Metric Alignment heuristic

The first group of heuristics describe how closely the rhythm aligns with the underlying metre. There are three separate heuristics in this group corresponding to three rhythmic variables: duration, velocity and timbre.

The metre is assumed to be provided (the Jambot has a separate module for metre induction). For this purpose we have modelled metre as a list of metric strengths for each beat in the bar, normalised to lie between 0 and 1. So, for example, if the time signature was 4/4 and we were quantising to quavers, then the metre might look like [1.0 0.125 0.25 0.125 0.5 0.125 0.25 0.125] with the downbeat having the greatest metric strength of 1.0.

The analysis consists of comparing the rhythmic emphasis of each note with the metric strength of the onset beat for that note. The rhythmic emphasis is a value between 0 and 1 representing the level of phenomenal accent of the note in each of the variables of duration, velocity and timbre. The velocity is already internally represented as an amplitude between 0 and 1, and so in this case the emphasis is simply taken to be the velocity itself. The duration and timbre are not so simple, and the emphasis for these variables is calculated by a hard-coded table. In the case of duration longer notes are more emphatic than shorter notes. In the case of timbre, notes are classified as being of low, mid or high pitch, with low notes being the most emphatic and high notes the least.

The value of the analysis is calculated by summing over the notes in the rhythm the absolute difference between the rhythmic emphasis and the metric strength of the onset beat.

5.1.2 Syncopation heuristic

The second heuristic is a measure of the syncopation present in the rhythm. Here a syncopation is said to occur when an onset occurs on a beat and *is not followed* by an onset at the next beat of greater metric strength. For example, using the metre described in section 5.1.1, if an onset occurred on the second beat (with metric strength of 0.125) and no onset occurred on the third beat (with metric strength of 0.25) then a syncopation would be registered. The level of syncopation is taken to be the difference between the two strengths, so in this example it would be 0.125.

5.1.3 Periodicity heuristic

The third group of heuristics describes the patterns of recurrence in time of note onsets. This is achieved by reporting on the level of periodicity present for a given period – where the period is an integral number of beats. All periods up to two bars worth of beats are reported on. The level of periodicity is taken to be value of the given period in the inter-onset-interval histogram for the rhythm, divided by the total number of notes. For this purpose an inter-onset-interval is defined as the difference in onset times of any two notes (not just successive notes).

5.1.4 Density heuristic

The last heuristic is a simple measure of rhythmic density. The analysis is calculated by dividing the number of notes in the rhythm by the number of beats. The beats here are the quantisation level, so that the maximum value for the density is 1.

As discussed above, the four groups of heuristics are combined single objective function by forming a weighted combination of the individual objective functions. In the next sections we give some very simple examples of the output of maximising this objective function, both with and without anticipatory timing.

5.2 Musical Examples

In this section we give some very simple examples of the musical output of the Jambot's rhythm generation, and compare the results with and without anticipatory timing. In the first two examples we attempt to find parameter settings for the rhythmic heuristics that result in a desired simple drum pattern. When using anticipatory timing it is easy to create these patterns with intuitive settings. Without anticipatory timing we were unable to find any settings that would result in these simple patterns. The third example demonstrates the output of the Jambot in an ensemble improvisation.

The point of these examples is to demonstrate that the use of anticipatory timing imbues our rule-based system with much greater control over the level of musical coherence in it's output.

5.2.1. Offbeat snare

The anticipatory timing approach seems to be most helpful when constructing rhythms that utilise a mixture of the metrical and non-metrical heuristics.

As a first example, consider trying to construct a rhythm in 4/4 quantised to 8 quavers, consisting of a kick on the downbeat, hi-hats on each crotchet beat alternating with snares on each quaver offbeat.

The heuristics that we use for the hi-hat are density, syncopation and a periodicity of 2 quavers. The density is set to 50%, since we want high hats on the crotchet beats, but not the quaver offbeats. The syncopation is set to 0% since we want the hi-hats to be on all the on-beats. Finally, we set a large weighting towards a periodicity of 2 quavers.

For the snare we use similar heuristics, except we target a syncopation of 100%, so as to force the snare drum to sound on the offbeats.

The resulting rhythm, using anticipatory timing, is shown below in figure 1. and can be heard in the example file: *AlternatingSnareAndHatAnticipation.mp3*.

Figure 1: Offbeat snare hits with anticipatory timing

However, using the same settings for the heuristics but without anticipatory timing results in the music shown in figure 2. and heard in the example file: *AlternatingSnareAndHatNoAnticipation.mp3*.

Figure 2: Offbeat snare hits without anticipatory timing

Without the anticipatory timing the hi-hat pattern remains intact, but the snare pattern is all over the place. One way to think about what is happening here is that the offbeat alignment is being forced by syncopation, but without anticipation the algorithm can't tell that a given offbeat is a good opportunity for a syncopation because it's not looking ahead to the stronger on-beat.

5.3. Example 2: Dancehall kick pattern

As another example we try to construct a 'dancehall' pattern with the kick drum, being a 3 + 3 + 2 rhythm in quavers in 4/4. The heuristics that we use are a combination of periodicities of 3 and 8. The periodicity of 3 on it's own would tend to produce a stream of 3 + 3 + 3 ... indefinitely. However, the addition of a periodicity of 8 constrains the rhythm to attempt to repeat itself every 8 quavers, and so we hope that this combination of settings should tend to produce the desired pattern, or a permutation of it (i.e., 3 + 2 + 3). To obtain the desired permutation, and have it align to the metre, we also specify the metric ambiguity heuristic to be low, meaning that the rhythm should adhere to the metre as closely as possible. The resulting rhythm (with a cow bell and clave click to show the metre), with anticipatory timing, is shown in figure 3 and can be heard in the example file: *DanceHallKickAnticipation.aif*.

Figure 3. Dancehall beat with anticipatory timing

To see the effect of anticipatory timing, note that the same settings without anticipatory timing gives the result shown in figure 4 and heard in the example file: *DanceHallKickNoAnticipation.aif*.

Figure 4. Dancehall beat without anticipatory timing

Without anticipatory timing the 3 + 3 + 2 pattern is lost.

5.4. Example 3: Ensemble Interaction

In the examples above the context for the Jambot's rhythm model has been a short window of history of its own musical actions. The Jambot is, however, primarily designed to be used for improvising in an ensemble, in which case the context consists of both its own musical actions and those of the ensemble. As an example of this mode of interaction we had the Jambot improvise in real-time to a pre-recorded drum loop, the infamous Amen Break, shown in figure 5, and heard in the example file *AmenBreak.mp3*.

Figure 5. The Amen Break

The heuristic settings used were just the density and syncopation for each of the hi-hat, snare and drum. The settings used were:

Hi-hat: density 95% syncopation 0%
Snare: density 33% syncopation 50%
Kick: density 33% syncopation 0%

The resulting rhythmic improvisations with anticipatory timing is given in *EnsembleAnticipation.mp3*. The Jambot's improvisation is relatively sparse, consisting of a repeated pattern of a few snare hits only. This is because the Hi-hat and the Kick parts in the loop are already sufficiently busy to satisfy the density target.

The snare pattern, to our ears, complements the input rhythm in a musically appropriate and coherent fashion.

The same settings without anticipatory timing produced the result heard in *EnsembleNoAnticipation.mp3*. As with the previous improvisation it is restricted to the snare. The snare pattern in this example is, to our ears, still interesting but less musically coherent than the example with anticipatory timing.

6. Conclusion

We have described a method for assisting real-time rule-based generative rhythm algorithms to produce more musical outcomes by anticipating possible future events and using this information as a constraint on committing to note generation (or early termination). We have examined previous computational approaches to real-time generative rhythmic material and seen that the use of future context is very rare. This is somewhat understandable given the exponential increase in computational expense normally associated with searching future outcomes.

Our approach of *anticipatory timing* uses substantial search tree pruning and limits future planning to one note, such that it allows for this approach to be practical in real-time generative music systems. We have provided examples of an implementation of this approach in the Jambot interactive music system that provide data that allow us to make provisional claims about the success of this approach in practical musical contexts. We conclude that the use of anticipatory timing provides an effective means for increasing musical coherence with a tolerable increase in computational complexity.

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

Cat Hope
Head of Composition and Music Technology

Stuart James
Lecturer in Music Technology

Kynan Tan
Honours Student

Western Australian Academy of Performing Arts
Edith Cowan University
2 Bradford St
Mt Lawley WA 6050

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.

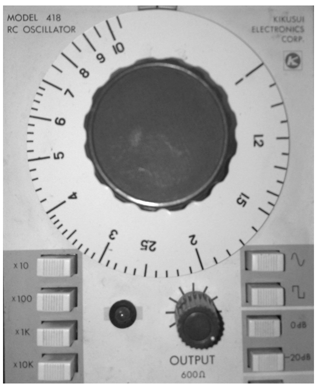

Figure 1: Kikusoi RC oscillator 418, showing the large dial.

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.

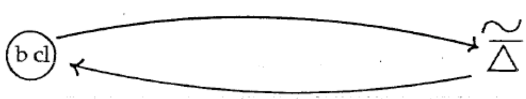

Figure 2: Lucier's drawing of the Bass Clarinet's spatial relationship to the speaker, taken from the score.

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.

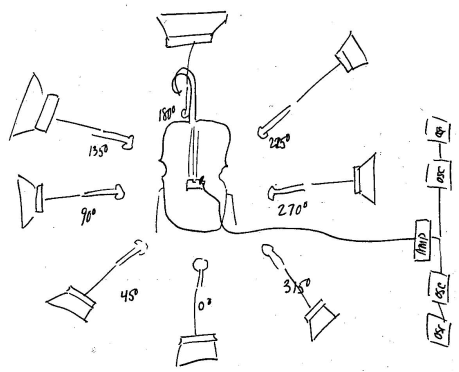

Figure 3: Lucier's own illustration of sound movement in *Directions of Sound From the Bridge* [8, 200].

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.

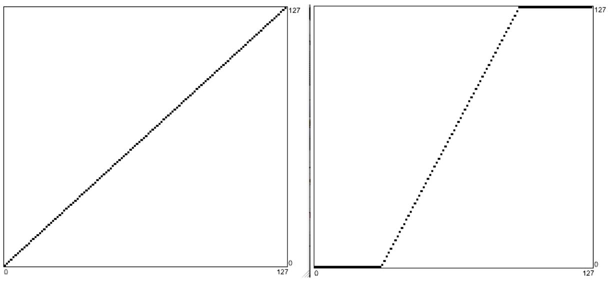

Figure 4: Two examples of response curves for LED intensity within Max/MSP; the one of the left showing the mapping for dimming and brightening, the one on the right maps a 'switching' effect.

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.

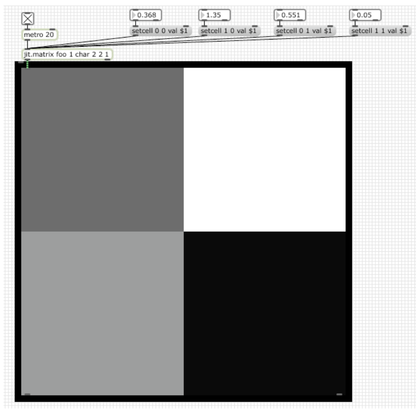

Figure 5: Max/MSP patch using Jitter to demonstrate different light intensities, black being off and white being on. Max/MSP patch by Kynan Tan.

[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.

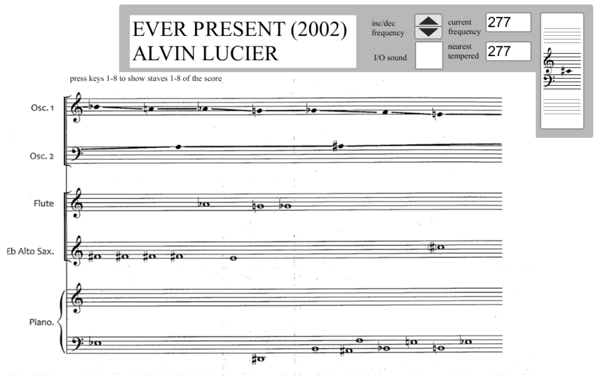

Figure 6: A page from the *Ever Present* score on a Max/MSP patch showing the notated sine tone parts (top two stave), and a simple sine tone player operated manully by a performer, relating pitch to noteheads and the tempered scale. Max/MSP patch by Lindsay Vickery.

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.

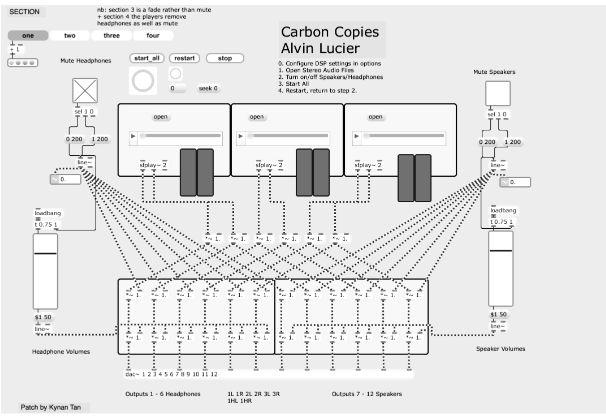

Figure 7: The GUI for the Max/MSP interface used in *Carbon Copies*. Max programming by Kynan Tan.

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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BRIDGING THE GAP: THOUGHTS ON COMPUTER MUSIC AND CONTEMPORARY (POPULAR) ELECTRONIC MUSIC

Sarah Keith
Macquarie University
Department of Media, Music, Communication and Cultural Studies

ABSTRACT

Two primary musical fields centred around the use of the computer in production and performance are computer music and contemporary electronic music. In recent years, music technology has become increasingly affordable and available to those with little or no musical training or institutional affiliation, giving rise to expanding numbers of practitioners whose engagement with music technology is informed overwhelmingly by their experience of popular and contemporary electronic musics. In this environment, it is interesting to consider the relationship between computer music and more vernacular forms, and how the omnipresence of music technology may lead to opportunities for engagement with wider musical contexts. Some key features of these fields will be discussed, taking as an example approaches to music performance using the laptop computer and the programs M and Ableton Live, as well as recent commentary in this area.

1. DEFINING COMPUTER AND CONTEMPORARY ELECTRONIC MUSICS

Despite the extensive involvement of electronic and computer technology in contemporary music, the academic focus of modern computer music possesses distinct interests separating it from broader contemporary music technology research. In and of itself, the term *computer music* is incomplete. Although it is a truism that computer music necessarily involves computers, the modern computer music field does not indiscriminately encompass all music composed on or with the aid of computers. Rather, it appears to have largely continued its inherited status as an exclusive and institution-centred domain. This has been achieved through a shift from a focus on technology to an emphasis on continued research and experimentation, continuing in the Western avant-garde and art music traditions.

Meanwhile, the contemporary use of computers in music composition and recording, while apparently using similar technologies to those used by computer musicians in the academic sense, can be viewed as a succession from older music production tools (such as tape recorders and analogue recording studios) to a newer and more efficient medium, with little calculated change in technique or sound.

The broader field of music produced with the aid of computers can thus be split into two sectors; firstly, the realm dominated by populist 'consumer applications' of music, as identified by Daniel Oppenheim [20], arisen from the commercialisation of analog or digital synthesisers and electronic music hardware since the mid-1960s. Contemporary electronic music is a prime example, consisting as it does of "sub-genre upon micro-genre of music which is based almost entirely upon, and impossible to conceive of without, the absolute regularity of tempo computers are capable of producing" [23]. The second, 'academic' branch of contemporary computer music, while necessarily engaged with technological issues, is founded more on the formalism, abstraction, and experimentation that has underpinned musical development in the twentieth century.

Examining the performance methodologies of computer music and contemporary electronic music reveals, not surprisingly, differences in their approaches to and conceptions of the music-making process. The latter term encompasses electronic music affiliated with (though not necessarily) popular music forms such as techno, dance, and electro which occur outside academic or institutional contexts. It also sheds light on how these approaches may complement each other to formulate solutions to the problems of laptop music performance.

2. PROBLEMS WITH PERFORMANCE

The use of the laptop in a performance setting presents a number of breaches to culturally instituted, normative definitions of performance. Qualities established and reinforced by acoustic and commercially-oriented performance are not inherent to the laptop medium, leading to a problematic disconnect between modes of musical production and reception in a live context.

Some recognised issues include perception of effortlessness [16] and non-liveness [14]. This can potentially be addressed through developing laptop instrumentality, focussing on expressivity, virtuosity [24], and perceptibility. Meanwhile, cultural antipathy towards technology in musical performance can be expressed as a tension between *pheno-text* and *geno-text* [8], where geno-text represents the desired and elusive grain, or 'human element' of performance, which is diminished by the integration of the machine.

Aside from these culturally-based challenges, the physicality of the laptop itself raises the issue of obscurantism and counterfeit [11]. To negotiate this, various techniques for literally or figuratively displaying the instrument have been explored, including screen projection and the implementation of additional, audience-scrutable interfaces. The role of the artist or author in performance provides an additional question framing the above issues, as this role is subject to different definitions and interpretations dependent on the performance context. Each of these matters is further complicated by the rapid rate of technological change, which continually introduces new technical possibilities for performance.

The complexity of these issues and their interrelationships, as well as the uniqueness of any performance situation, precludes any definitive solution to the performance of computer music and contemporary electronic music. Nonetheless, they can be used to formulate an individual approach, informed by an awareness of the surrounding issues.

3. MEANS FOR RECONCILIATION

The most self-evident factor connecting computer music research and contemporary electronic music performance is the centrality of the computer to the musical process. Chadabe [12] suggests that these fields are likely to intersect, citing wider social forces contributing to the integration of popular music culture with elite 'high-art' computer music. This merge, according to Chadabe, may occur through the invention of applications that allow the public at large, with little or no computer-specific musical knowledge, to "interact in a sophisticated and creative way with a musical process" [13].

Although the literal interaction of an audience with musical processes is a concept more suited to a gallery or experimental happening than a dance-floor, the notion of sophisticated and creative computer-based interaction with musical processes has immediate applications for contemporary electronic music performance. Furthermore, the specific area of contemporary electronic music performance is well suited to researching new interactive possibilities. Chadabe [13] suggests that a possible role for computer music research is as a facilitator of musical processes and tasks for the benefit of those outside of the immediate computer music field.

Neill [22], expanding on many of the points raised by Chadabe [12] likewise asserts that interactivity may serve as the focal point for an integration of computer and popular musics. Integrating computer music and popular music culture can thus also be based on the practical pursuit of musical interactivity in a performance context.

4. PERFORMING CONTEMPORARY ELECTRONIC MUSIC

The performance of contemporary electronic music has evolved from, and is enduringly linked to, turntable technology. The use of turntables in performance is notionally limited by the performative and sonic conventions of musical genre. Virtuosic turntablism, prevalent mostly in hip-hop, provides the most extensive control over musical material. In electronic music, limited DJing practice is the norm, resulting in a more functional than creative role for the performer. The turntable model remains a widely accepted and well-understood performance formula for contemporary electronic music. Commercial technological developments on this model include CD turntables and DJing software, which address practical issues rather than broader issues relating to the nature of musical performance.

Given that turntables and their technological descendants have evolved from systems of music *consumption* (the vinyl artefact) rather than *production*, it follows that the logical extension of this limited approach is the incorporation of tools for the production of electronic music into performance contexts. Synthesisers, samplers, sequencers, and audio processors allow, at first glance, greater interaction with musical material. A practical implementation of these technologies to performance is complicated, however, due to their lack of specialisation for real-time contexts and the multi-layered complexity of contemporary electronic music.

Using production technology therefore necessitates a compromise between interactivity and improvisational potential, and a satisfactory level of musical complexity. In order to make full use of music production technology in performance, it is necessary to develop intuitive and reliable communication between performer input and a complex musical result. This provides a valuable opportunity for practical research into generative and other algorithmic music composition and performance techniques.

5. COMPARING M AND ABLETON LIVE

The different approaches to musical performance espoused by computer music and contemporary electronic music can be understood by examining two programs: M, distributed by MaxMSP developers Cycling '74 [15], and Ableton Live, developed by Ableton AG [7].

Ableton Live merges aspects of production and performance, relying on the DJ paradigm of cueing sections, breaks, and loops. The practical aspects of the DJing process are greatly facilitated by Ableton Live's software interface. M, on the other hand, builds an original interface for generative and algorithmic computer composition and performance.

The drawback of Ableton Live's usability, context-specificity, and comprehensibility is its normative and limiting view of performance. Conversely, the disadvantage of M's expanded performability and interactive potential is its lack of defined musical and cultural context, which contributes to its complexity and relative obscurity outside the computer music community.

5.1. M

M, written by a team of developers including David Zicarelli and Joel Chadabe in 1986 [17] and still currently available, represents a notable early foray into the domain of software capable of being used in both composition/production and performance contexts. This program generates MIDI output rather than audio data and allows the user to algorithmically process supplied content, generating new material from this information

[29]. M also incorporates performance controls, allowing users to map keyboard, mouse, or MIDI input data to program instructions [29].

The M user manual states, "M's powerful tools and musical controls let you work so quickly and interactively that the line between composing and performing becomes blurred" [29]. Despite this promise, the forbidding complexity of possibilities for algorithmic composition, control, and performance, combined with M's lack of embedded musical context, contribute to M's predominant position as a primarily academic compositional tool, precluding a more widespread use or acceptance by the music community at large. An online history of M by Cycling '74 is reticent about listing specific composers or performers who have used M [17], and therefore, apart from prominent figures such as Chadabe, the actual extent and method of its use is difficult to discern.

Nonetheless, M is worth mentioning as an example of a program that directly addresses early concerns regarding the problematic aspects of performing computer-based music in general, despite the ambiguity of its known use within contemporary electronic music.

5.2. Ableton Live

Given the advent of affordable home computers powerful enough to permit significant audio handling and processing, the capability of software programs that incorporate both composition and performance has greatly increased in recent years. One such program is Ableton Live, available since 2001 [7] and in its eighth version as of early 2010. This widely used recording and performance environment is particularly prevalent within contemporary electronic music. Ableton AG, creators of the program, estimate the number of users at "several hundred thousand" [7], and provide a list of prominent Ableton Live users on a dedicated section of their website. Of 65 artists listed, 35 are described as either DJs or electronic musicians [2]. The program is billed as a product that "accompanies every stage of the musical process, from creation to production to performance" [3]. The central function of Ableton Live is as digital audio workstation software, which operates similarly to comparable programs such as MOTU's Digital Performer, Steinberg's Cubase, or hobbyist programs such as Apple's Garageband.

A multi-track sequencing and recording environment is the core of this basic functionality, allowing both audio and MIDI arrangement as well as features such as audio or MIDI effects and processing, software synthesisers and samplers, and the ability to capture audio or MIDI from external sources. Where Ableton Live crucially differs from these programs is in its attention to real-time use and performance. It includes a dedicated performance dimension, called Session View, as well as Arrangement View, which represents the standard multi-track recording environment described above. Using Session View, the user can choose from a large number of pre-loaded or recorded audio or MIDI segments ('clips') for uninterrupted, looped clip playback, unlimited by the temporally linear restrictions of a traditional multi-track environment. This feature is described on the Ableton Live website as "a powerful musical sketch and launch pad, allowing you to improvise freely with ideas" [4]. The notion of switching between modular looping sequences is commonly demonstrated in many hardware and software sequencers and is often a key feature of contemporary electronic music production. Given the colour-coded visual display, and the point-and-click interface of Ableton Live's Session View, this practice is developed into a considerably more user-friendly procedure, as graphically represented clips can be easily organised, cued, and recalled by the user.

Although Ableton Live is closely allied with the technologies of music *production*, the particular influence of computer-based DJing environments on the *performative* aspects of Ableton Live is worth considering. The popularity of Ableton Live among DJs has been mentioned, and specific features tailored for DJ performance are embedded within the performance system. Facilities for tempo induction, beat-matching and quantisation, headphone pre-audition, simplified cueing, effects, independent pitch and tempo adjustment, and EQing are included [5], replicating features found in software and hardware DJing technologies.

Ableton Live's performance capacity is introduced by the statement, "in all traditional sequencing programs, everything happens along a fixed song timeline. For a number of applications, this is a limiting paradigm", citing DJ performance, live sound for theatre, and film scoring as examples where a linear approach is not appropriate [6]. Session View, which allows sound clips to be layered, arranged, and selected in real-time, is thus a concept that is unusual when considering multi-track recording software, but a central feature of DJ software and practice [6].

There is necessarily some trade-off between ease of use and customisability, and the inflexibility embodied by Ableton Live's implicit focus on DJ practice is discussed by Blackwell and Collins [9], in a comparison with live coding. The authors cite Ableton Live's representational assumptions, such as an initial 120bpm tempo and 4/4 time signature, to illustrate the program's tendency to constrain and predefine user decisions [10]. The central advantage of Ableton Live thus lies in the unity of its recording and performance environment, rather than the DJ-influenced nature of the performance environment itself, consolidating the user's influence over the musical process as a whole.

5.3. Comparison

Comparing Ableton Live and M reveals some striking differences, although the stated objective of both programs is to consolidate the habitually separated fields of music production and performance.

M, described as an "intelligent composing and performing system" [15], places an increased emphasis on compositional interactivity with the program. This definition of M as a composing system is a key factor in identifying its difference from Ableton Live in performance, as M itself has creative input. M situates the fields of composition, recording, and performance as aspects of a single undertaking, rather than separate stages in the music-making process.

Meanwhile, Ableton Live shows more detachment between the composition/recording and performance processes, demonstrated by its separation of Arrangement View, for multi-track recording, and Session View, for performance purposes. Although it is possible to record live 'takes' from the Session to the Arrangement View, Session View requires a concrete repertoire of MIDI or audio material to be composed or sourced beforehand, effectively compelling production to precede performance.

M's approach to composition, recording, and performance is more holistic. Rather than requiring pre-composed material for recombination, the performer specifies types of behaviours, reactions, and patterns that are executed by the program in performance, or in real-time at least. In effect, using M involves creating material *generators* rather than material itself, therefore directly linking the operations of composition and performance.

Ableton Live and M may both be justly described as performance programs that provide an alternative to the paradigm of "being bound to a fixed timeline" [1]. This distinction involves firstly a straightforward difference of interactive scale. Both programs allow interaction at the *meso*- and *macro*-level, to use Roads' terminology [25], while only M offers interaction at the *sound object* level, and Ableton Live offers increased timbral interactivity. More importantly, there is a fundamental conceptual difference between these programs regarding the ways that composition and performance are related, as illustrated in Figure 1.

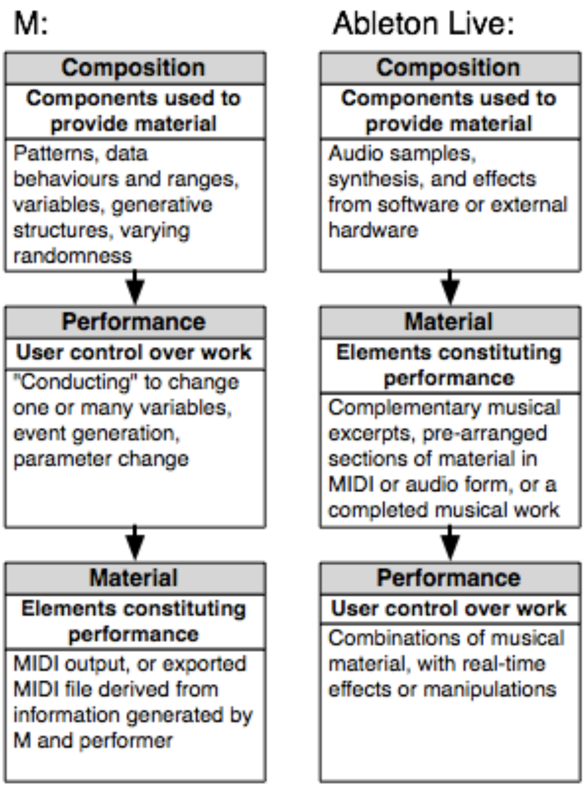

Figure 1. Contrasting relationships of performance/material in M and Ableton Live

There is certainly a degree of flexibility in the usage depicted in Figure 1, depending on the user and the features used in each program. Similarly, although the exact definition of the terms used, including concepts of composition, material, and repertoire, are open to debate, Figure 1 serves to underline two fundamentally different approaches to performance.

As an example, the concept of repertoire varies when applied to works created in M or in Ableton Live. Both programs require a repertoire of sorts in order to successfully enable performance. Ableton Live's repertoire consists of ready-made musical fragments assembled within the work in question, whereas M's repertoire differs in that it consists of indeterminate musical behaviours realised only through performance.

M thus embodies an *a priori* relationship of performance to material, as composition of and within the performance environment requires a theoretical deduction of the material that will result. Conversely, Ableton Live illustrates an *a posteriori* approach to performing musical material, as components are prepared beforehand and outcomes react linearly to the performer's actions. The pivotal ontological difference between M and Ableton Live is thus the centrality of the element of performance.

5.4. Performance attributes

This difference notwithstanding, Ableton Live and M both offer valid solutions to the rift between production and performance within computer-based music.

M extends performance by consolidating composition and performance into elements of the same activity through the use of generative and algorithmic processes. It also permits real-time interaction at the sound object level. Ableton Live extends performance by positioning it as an ancillary to a fully-rounded production environment, and furthermore provides extended control over musical result by allowing the performer to use self-composed material. The primary benefit of Ableton Live is its integration of production tools.

The compositional and performative possibilities embodied by generative processes and demonstrated by M, however, represent a different notion of performance that is not derived from DJ practice. Here, new material at the sound object level can be generated in real-time. The idea of real-time composition and improvisation in contemporary electronic music—a genre characterised by complex rhythms, timbres, and arrangements—is compelling. By adding layers of complexity and uncertainty, the user/performer is obliged to interact with the resulting musical material, producing an evolving dialogue rather than relying on a determinate, uni-directional flow of activity.

Improvisation has particular value for the single-performer-and-computer model, as external musical influence in the form of either collaborators or instrumental input is absent. This can run the risk of developing a 'closed circuit' in which the performer bears complete responsibility for navigating a fixed musical space. By developing a more reciprocal interchange between human agents and performance software, the concept of performance in contemporary electronic music is expanded from a reliance on pre-built arrangements, loops, and structures, to one that incorporates elements of real-time music creation—focussing on creative interaction, improvisation, and immediacy.

6. ENGAGEMENT AND RECIPROCITY

There is significant tension engendered by trying to insert a performance dimension to a musical form such as contemporary electronic music, as it is based almost entirely in 'off-line' studio production. The performer firstly does not possess the physical and mental capacity to perform these complex musical works in the same one-to-one physical-gesture-to-acoustic-result capacity as an acoustic musician. Ensemble performance would increase the possible complexity of musical output, but although computer music laptop orchestras abound, little precedent exists for contemporary electronic music.

Using the computer to facilitate performance triggers many questions: what aspects of the musical work should the performer interact with, to what extent, and how should this occur? Will increasing interaction diminish the quality of the musical result, or will limited interactions diminish the quality of performance? Furthermore, how can the audience—both habituated to the musical work as a product of the studio, and instilled with notions of acoustic performance—be satisfied with what this type of performance offers? These questions are perhaps not definitively answerable, but searching for solutions across both contemporary electronic music and computer music at least offers additional perspective.

6.1. Recent developments

It is difficult to say whether any significant reciprocity, in a creative sense, has developed between computer music and other fields of research or musical cultures over the past decade. Certainly around 2003 interest in the laptop computer as a means of performance, and in the commonality between glitch and computer music, seems to have peaked (see [26], [28]). Presently, the laptop as a creative instrument in this field endures mostly through live coding and through the formations of various laptop orchestras (see [27]), but on the whole the continued association of computer music with primarily classical (Western or non-Western), jazz, and experimental contexts remains intact. It has been somewhat surprising that so few investigations treating contemporary electronic music have occurred during this time.

Furthermore, concerns about the lack of triangulation or detachment of computer music, such as those raised by Landy [18], Chadabe [12], Zicarelli [30], or Ostertag [23] have largely abated, although a brief and timely commentary by Myatt [21] should be noted. In retrospect, it seems probable that the proliferation of the laptop computer circa 2001 led to a spate of live music-making and experimentation by both academic and non-academic composers, similar to other new technologies in recent years such as RFID tags, the Nintendo Wii controller, and the Apple iPhone which have likewise experienced arcs in popularity. This common focus has since subsided following the diminishing novelty of the laptop, and the establishment and increasing ubiquity of commercial performance software such as Ableton Live.

Despite the persisting distance between computer music research and contemporary electronic music, popular music, and non-academic computer music, it is hoped that the fruitfulness of integrating or at least considering these areas has been demonstrated.

6.2. Future developments

Recent years have shown little discernible increase in the relationship between computer music research and more popular music forms, a number of intrepid live coders notwithstanding. It would be reckless to suggest that there is an impending flood of computer musicians and researchers who will address this issue. Any progress in this regard from the direction of the computer music community at large is likely to be gradual, and a 2006 statement by Eric Lyon is telling. He affirms, concerning the reciprocality between popular and computer musics, that "this influence has worked both ways, with increasing numbers of academic computer musicians incorporating beat-oriented, tonal or other vernacular elements into their computer music" [19].

If beat-orientation and tonality are, in 2006, still considered vernacular and relatively unusual elements, future significant developments in generative composition and performance of contemporary electronic music will most likely originate from non-academic quarters. Artists, software designers, and programmers with an interest in contemporary electronic music constitute a community that is both dynamic and unpredictable.

7. CONCLUSION

Performance in contemporary electronic music is ripe for investigation, and leads to additional explorations of improvisation, interactivity, and creativity, both in this and further musical contexts. As a tool for performance and real-time interaction, the computer is still a relatively new instrument. The ubiquity of the laptop computer in particular, and the increasing accessibility of music software combine to provide an ever-growing population of potential meta-composers and performers. It is hoped that computer music research, as well as other research fields and non-academic practitioners of contemporary electronic music, will engage with this possibility.

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AESTHETIC IMPLICATIONS OF THE ECO-STRUCTURALIST PROCESS

Timothy Opie
Queensland University of Technology & Box Hill Institute, 1000 Whitehorse Rd, Box Hill, VIC

Andrew R. Brown
Queensland University of Technology, Victoria Park Rd, Kelvin Grove, QLD

ABSTRACT

This article explores the aesthetic implications of eco-structuralism. Eco-structuralism is a method of music composition that utilises the sonic features of natural sounds as structural elements in new compositions. This paper places eco-structuralism within an aesthetic and analytical framework. It explores views of aesthetics and nature and discusses how eco-structuralism is positioned in relation to these ideas and considers some aesthetic opportunities of the eco-structuralist process.

1. INTRODUCTION

> *We can hear sounds whose meanings are not intended for us as if they were music and soon call them beautiful. This is part of music's power [19].*

For a long time people have contemplated the connection between sounds in nature and musical sounds. The process of eco-structural composition is a computer music approach that exists within this tradition. Eco-structuralism is a formalised musical composition technique that uses structures derived from sound recordings to dictate the compositional process. This technique takes a serial approach to the collected data [16].

This paper will explore various aesthetic and analytical considerations that are raised by eco-structuralism. It will, firstly, consider various views on aesthetics, and then various views on analysis. These considerations will be used to understand some of the musical implications that arise in this compositional technique, and to suggest how these implications allow a more extensive understanding of eco-structuralism.

2. AESTHETIC CONSIDERATIONS

For many composers nature has been an inspiration and a metaphor for music. For others, the imitation of nature has been a source of musical material. Such mirroring of nature was, according to Rothenberg [19], an "aesthetic dream" of John Cage and goes as far back as Aristotle's vision of *techne*. At one level, all environmental sounds can be heard as music, and it was in this direction that Cage was inclined. The imitation or mirroring of nature includes the imitation of bird song as melodic themes and, since the advent of sound recording and the techniques of musique concrète, the direct and manipulated use of environmental sounds as musical materials.

The process of eco-structuralism employs the forensic capabilities of digital signal processing to examine the microstructures of natural sounds and uses those data as compositional building blocks. This inevitably places eco-structuralism within the debate on aesthetics and nature. A question remains, however, about whether eco-structuralism implies the kind of psychological reaction that conflates arts and nature in Cage's conception, or if there are more subtle aesthetic implications in the translation and reinterpretation of structural elements that eco-structuralism employs. To delve into this we need to revisit some of the background of the shifting sands of aesthetic debate.

The term aesthetics has been in use since Alexander Baumgarten first used it to distinguish between knowledge and perception of art in 1735. His idea of aesthetics was to understand how we perceive or experience art [3]. Immanuel Kant in 1790 provided aesthetics with a much more universal approach. He proposed that art be viewed from a disinterested perspective; a detached or disengaged perspective would allow the critic, he argued, to make a more pure more universal judgment on the artwork [5]. The disinterested position enabled the critic to avoid the temptation of seeking and proving pre-determined outcomes. Kant was also of the opinion that music is of such a transient state that although it can suggest sensation, it cannot articulate any precise concept or meaning [3]. In contrast, Hegel took up a counter position, stating of music:

> *This earliest inwardness of matter and inspiration of soul into it furnishes the medium for the mental inwardness itself as yet indefinite and for the soul into which mind concentrates itself; and finds utterance in its tones for the heart with its whole gamut of feelings and passions [4].*

Nietzsche and Schopenhauer along with many other philosophers extended this emotional view on the musical aesthetic, with Schopenhauer (1819) stating, "Music…is such a great and splendid art, it creates such a powerful reaction in man's inmost depths, it is so thoroughly and profoundly understood by him as a uniquely universal language, even exceeding in clarity that of the phenomenal world itself" [13]. This idea led the way for many varied aesthetic ideas on the notion of feeling and emotional content in music. This perspective on aesthetics allowed the discourse to become very subjective.

Hanslick took a functional perspective and refuted the claim that music contained any emotion whatsoever saying:

> *The course hitherto pursued in musical aesthetics has nearly always been hampered by the false assumption that the object was not so much to inquire into what is beautiful in music as to describe the feelings which music awakens.* [11]

Hanslick went on to claim that "art aims, above all, at producing something beautiful which affects not our feelings but the organ of pure contemplation, our imagination" [11]. His view of music aesthetics was a reductionist idea that "Music has no subject beyond the combinations of notes we hear, for music speaks not only by means of sounds, it speaks nothing but sound" [11]. Hanslick argued that sound and music have momentum. What we hear, and what we recognise is not a shift or change of expressed emotion, it is more directly an expression of change and motion in tone, and within that lies the means for aesthetic expression.

Eli Siegel based his ideas somewhat on those of Hanslick, but developed an aesthetic philosophy called Aesthetic Realism. It is described as "a way of seeing reality as a whole" [10]. The core principle of Aesthetic Realism is that:

> *"there is no fundamental difference between the structure of reality and the structure of beauty. Moreover, the very nature of self is aesthetic". [10]*

Aesthetic Realism takes a structuralist approach to aesthetics, but relies on an aesthetic dialectic to explain art, nature, and reality. It shares with structuralism an appreciation of the organisation of nature but understands nature to contain dialectic structures or patterns or tendencies and seeing beauty in the balance of these dualities.

Roger Scruton, in opposition to Aesthetic Realism, devised a non-realist approach to aesthetics, in which he reintroduced the emotional or experiential discourse into the debate on aesthetics. His theories were influenced by those of Schopenhauer. Scruton [21] identified five key points that need to be considered in an aesthetic of music. They are:

1. Music does not represent objects or actions, except at the margin.

2. Nevertheless music is often meaningful, in the strong sense that there is something to be understood in it.

3. Listening to music is an expression of aesthetic interest, and music is understood through the aesthetic experience.

4. Music is not a language, even if it is like a language in certain respects.

5. The expressive qualities of a work of music form the most important part of its content.

Scruton emphasises the use of ordinary words as metaphor in the discussion of music. These metaphors, he suggests, play on our imagination in order to evoke emotion.

Nick Zangwill, in response to Scruton and building on the Aesthetic realist approach to understanding music, extends the realist philosophy and criticises Scruton and other non-realist aestheticians, claiming that "Emotion is a thorough distraction when thinking about the nature of music" [22].

We can see that there is a debate in the world of aesthetics between the significance of structure in the musical object on the one hand and human perception and experience of the musical object on the other. It is not our intention to resolve this in this paper, but it is necessary to point out that the aesthetic implications of eco-structuralism are clearly more closely aligned with those who suggest that there is meaning and beauty in the structure of artistic objects that is somewhat independent of individual perceptual differences.

Eco-structuralism is concerned with how structures in the natural sound world can become generative materials for musical composition. Therefore we will next focus on the connection made between nature and aesthetics, which is the aspect of aesthetic theory which most directly impinges on eco-structuralism.

3. AESTHETICS OF NATURE

Plato gave the first template for an aesthetics of nature when he introduced the idea of the form. The form, he stated, is the universal prototype of everything in nature. Any tree is striving to achieve the pure form of "the tree". It will never achieve this perfect form, because it is an imperfect tree in an imperfect world, however, it strives regardless toward that form. The beauty of the tree can be gauged in considering its participation in realising the form [18]. This idea was also used, in part, to establish the idea of mimesis, a philosophy and practice where the artist tries to mimic nature.

Kant also wrote about the aesthetics of nature. He ascribed the aesthetic experience of nature to be only basic, when compared to the experience of artistic beauty [20]. Kant went on to suggest that

"The aesthetic pleasure of nature comes about only if an object's form agrees, accidentally, as it were, with a form that the imagination could have invented on its own. It is the comparison of the actual form with the counterfactual form that decides on whether we judge the object to be beautiful". [20]

This idea is somewhat similar to that stated by Plato, except that the form presented by Plato, and that presented by Kant have a different place of origin.

Another sceptical view of nature and aesthetics was held by Hegel who suggested that when judging the beauty of nature we feel significant vagueness and that such judgements lack sound criteria. He proposed, therefore, that an aesthetic theory could not be constructed on the beauty in nature. Instead, such a theory should be relegated to the realm of high art where objective categories are possible [20].

Schopenhauer, in his commentary on aesthetics, was also cautious when contemplating the aesthetic appeal of any individual natural object. He did, however, comment on the aesthetic appeal of a natural ensemble of objects. He was, perhaps, unable to accommodate his insights of the aesthetics of nature within the structure he had proposed previously with art [8].

Malcolm Budd provides a comprehensive coverage of aesthetics and nature. He describes how some people undertake a discourse about the intrinsic aesthetics of nature that others observe nature as a creation of God and appreciate it for its ingenious construction, as did Messiaen. He draws a parallel with aesthetic appreciation of art, where some appreciate the object while others the artist. Budd, however, makes the distinction between that which is man-made, and that which is not. He states that an aesthetic appreciation of that which is not man made must be made on its own terms, and not in considering nature to be an artefact. When you hear birdsong the aesthetic experience, he suggested, is not in hearing a pattern of sounds, and is certainly not a sound intentionally determined by artistic consideration, instead one delight's in the effortlessness of "the sounds issuing naturally from a living sentient creature, more specifically, a bird" [8]. He goes on to state that the function of the song is not to provide us with pleasure, but instead to attract a mate, or affirm its territory[1]. This, however, need not detract from an aesthetic response.

An attractive conception of the aesthetic represents a response as being aesthetic insofar as the response is directed at the experienced properties of an item, the nature and arrangement of its elements or the interrelationships among its parts or aspects, and which involves a felt positive or negative reaction to the item, considered in itself, rather than as satisfying a pre-existing desire for the existence of something of that kind, so that what governs the response is whether the object is intrinsically rewarding or displeasing to experience in itself. [8]

In this way, a person can make an aesthetic judgement based on their experiences with that work at that present time, the aesthetic qualities are not predetermined by "arrangement of its elements". Following this position, a composer using the eco-structuralist technique will choose a sound based on their experience of that sound hoping to imbue their final composition with some of those same characteristics which formed that initial experience, but at all times the composition will itself be judged as to its intrinsic value and a transfer of aesthetic experience is in no way guaranteed. The eco-structuralist composer is still responsible for crafting the aesthetic potential of the work.

4. ANALYTICAL CONSIDERATIONS

The rise of modernist influence in music, especially in techniques such as Schoenberg's 12 tone series led to a focus on the *form* of music, and eco-structuralism as a kind of serialism also privileges form. However, formalism has roots as an aesthetic approach in the nineteenth century, well before serialism, with its chief source of promotion found in Kant's *Critique of Judgement* [15]. In this sense it was Formalism that gave precedence to formal structure of music as its essential defining characteristic. At a time when orchestration and compositional structure were seen to be somewhat independent this may seem uncontroversial, but for computer music composition where timbre and spectral morphology are understood as significant then formalism may require a more subtle definition.

The writer Eduard Hanslick [11] provided an influential view of formalist musical aesthetics in the mid nineteenth century. His views of musical structure went beyond the mathematical to embrace the metaphysical and the notion that the musical structures somehow contained the spirit of the composer or their thoughts.

In more recent times, much of the analytically-based computational musicology research, for example that by David Cope, David Huron and David Temperley, could be argued to implicitly follow a formalist view of music without the metaphysical overtones.

[1] Hartshorne has investigated bird song to find that some birds derive both aesthetic and musical pleasure from their own song [12]. To propose that the bird is the composer is however an issue not investigated, and beyond the scope of this research.

Theodor Adorno wrote numerous papers on aesthetics in which he explored and expanded on Kant's original aesthetic ideals; one issue that deserves exploration in this context is the way he situates the aesthetic judgement of autonomous (or disinterested) music within the political (Marxist) realm. He argues that the impact of culture informs the musical process, and forces the composer to mimetically express authoritarianism, in order to give it a false sense of emancipation. He stated that "art is the sedimented history of human misery" [1].

While generally trying not to engage in political interpretations, Structuralism accepts the impact of culture on artistic appreciation and production, and indeed actively seeks to find traces of culture and identity within the art work. It is an analysis method whereby objects can be interpreted or studied in a framework of communication. The Structuralist acknowledges the ability of structure to carry meaning. They will use the structure of an art work to convey a message, and they will analyse art work assuming the same intention. The beauty therefore is inherent in the structure itself [3]. An understanding of social and cultural activities takes on an analytical importance as a source of signs to look for in a structuralist interpretation [2].

A reinterpretation of structuralism was undertaken by the postmodernists, in which the emphasis of interpretation is placed on the observer rather than the creator. It still accepts the communicative power of structure, however it also identifies the problem in which the structure alters the context or perspective of the message [3].

Eco-structuralism is clearly an approach with structuralist tendencies. Analytical methods appropriate to eco-structuralist works will likely involve analytical deconstructions of the materials and their form to observe the sources and elaborations of materials in the work. However, the social and possibly even political resonances in the source materials in particular cannot be overlooked, especially in the 21st century where ecology and the natural environment are hotly debated topics in society.

5. MACHINES AND NATURE

There may seem to be an obvious disconnect between the discussion of computer music—often made by mechanical means—and nature, especially natural sounds, processes and structures. This dialectic becomes especially critical when examining the heavy computational, analytical and even compositional processes that are undertaken by a computer in eco-structuralism. There is often considered to be a great distance between the natural and man made, and an even greater distance to the machine made. Budd commented, for example, that man made may be 'bad enough' but machine made is even further removed [8].

How might we reconcile this apparent distance, and what is the impact on the aesthetics of the work when significant creative control is devolved to the eco-structural processes and the computer? This idea is especially compounded when one considers that computer programming is invoked as a self-reflective task, rather than an exploration of the natural structural richness. However, we suggest that this line of argument can get problematic, especially if music is considered a human construction and therefore perhaps, as Heidegger might suggest, simply another technology.

This dilemma can, however, be avoided if one considers the computer to be an extension of the human. The computers agency is a delegation on behalf of human agency and ultimately controlled by human artistic decisions. The computer does provide a place for ideas to be developed and expanded upon without the limitations imposed by the real world or even the human mind. This increased capacity allows a composer to take real world structures and use them in a new structural context, transforming them into art forms for musical expression, treating the computer as an assistant in the process [7].

Another interesting angle on this discussion of nature and machines is that some might consider nature as a machine [9], and thus the project of eco-structuralism seems to be simply a transduction from one machine structure to another. However, while eco-structuralism is a technological enabled process we generally intend that it is a tool for music making and so we recall Lanier's advice that; "Music must not be seduced by technology but must seduce technology" [14].

At the opposite end of that argument is the notion that humans and the machinations of humans are a part of nature [17]. David Dunn has performed many explorations in nature that incorporate a human made sound being projected into nature to capture how the environment responds to it. He views the sounds of humans and human devices as an act of communication within the natural environment [17].

Aesthetics are driven by limitations and opportunities of human perception, culture, and tools. Musical structures typically arise from any of these sources and eco-structuralism attempts to add to the richness of compositional processes and techniques by considering the natural environmental context as a source of compositional inspiration. So it is the aesthetics of eco-structuralism that we will now consider in more detail.

6. THE AESTHETICS OF ECO-STRUCTURALISM

In defining the aesthetics of eco-structuralism, we need to dissect the components of the process and give each component a weighting of importance and relevance to the overall scheme of eco-structuralism. In this way we can determine aesthetic values of the components that relate most directly to the intrinsic process of eco-structuralism.

The source material (sounds) from which the structural content is derived has aesthetic significance, however, we know that there has been no compositional process or any kind of artistic endeavour that has created the sound. Plato and Kant have both stated that nature has a form which it aspires toward, and by which we can assess the aesthetic state of nature. Hegel and Schopenhauer, however, feel that an assessment of aesthetics in nature is unnecessary. Budd has stated that our appreciation of nature occurs when we undergo aesthetic dialogue. Such a dialog can occur between composer and listener. The composer makes the first statement by choosing and has given the sound merit by using it as a sound source. According to Budd there is an opportunity for a response by the audience in noticing and appreciating these choices in what they are hearing, potentially enhancing their aesthetic experience.

We feel that a combination of the formalist ideas and the appreciation model can work well together in understanding the aims of eco-structuralism.

Once the composer has selected a particular sound due to its aesthetic qualities, eco-structural processes allow them to analyse the natural sound with the intention of transferring some of these qualities to the composition. The philosophical idea underpinning the success of eco-structuralism is that there is some change and motion within the source sound that can be successfully captured and applied for artistic endeavours. The structures in nature are in essence templates or forms with aesthetic potential that become building blocks for new musical compositions.

The eco-structural processes measure change and motion of various parameters within the sound recording. The approach seeks to uncover some archetypal structure in order to use this structure to imbue their artistic endeavour with similar natural motion. It is recognised that this is actually a reductionist approach. Within the analysis process there is a diminution of integrity through the separation of elements within the sound that alters the structure or affective potential irreparably. This is a limitation that cannot be altered, and must occur because the context of the structure is being altered on a huge level. However, in our experience there is often one or two significant elements (especially amplitude and pitch contours) that carry much of the character of the original sound.

A third stage of eco-structuralism is the actual compositional task in which the composer decides which structures to use, where to use them, and what kind of timbre they will associate with the structures. From an observer's point of view, this process presents a higher level of aesthetic engagement, as it is what the listener is presented with. The initial structure of the natural sound is clouded with unnatural timbres and unnatural beginnings and endings. This is the melding of nature with artist, the motion of the natural sound with the designed artistic gestures.

So in the end, what does eco-structuralism achieve? It affords the aesthetic appreciation of natural motion, insomuch as it can preserve the structure containing the aesthetic through the tumultuous post-structuralist convolution.

Due to the heavy handed nature of the structure in this process, an Aesthetic Realist approach would be the simplest way to approach any discussion on the beauty in eco-structuralism. This approach would allow a discussion on the aesthetics of nature and on art, which as Eli Siegel has stated share the same basic structure.

7. AESTHETIC POTENTIALS OF ECO-STRUCTURALISM

In a compositional system that seeks to preserve natural motion within a music structure, there are certain aesthetic potentials that provide particular value in a musical and compositional context. These include the fact that nature provides a rhythm and a natural series of events that may seem very random to the casual observer, however, when compared to true randomness these events are merely irregular. This natural irregularity is something that offers many musical possibilities. When used as a compositional structure it could dictate when certain musical events take place; such as a phrase change, a musical accent, a rest, a change of musical instrument, change in tempo, a new movement, the rhythmic pattern or melodic pattern for a melody or harmony, etc.

Natural irregularity can also be used more directly in sound generation processes to produce and modify tones. One specific method we have been working with is to use the eco-structural data as a waveshaping tool. One of the benefits of this process is that it allows the composer to easily add colour to a simple sine tone in a controlled and repeatable manner. The same data can be applied to any sine wave tone to add the same colour across an entire range of pitches. As an example of this process we compare five different generated tones. Each tone began as a sine wave. The eco-structural data chosen for this was an amplitude structure generated from the file "boulanger-beach.au", a 25 second seaside sound event captured at Aruga, from the OLPC CC collection by Dr Richard Boulanger.

The first tone is the simple sine wave at 320Hz. This unaltered sine wave can be easily generated, although it is very unnatural and clinical sounding (See figure 1).

The second tone was generated by adding the eco-structural data to the sine wave using the waveshaping synthesis method. The generated waveform was reduced in amplitude very slightly to avoid clipping at a couple of points. This waveform quite visibly and audibly has a certain roughness and colour, without disturbing the pitched quality of the tone (See figure 2).

The third tone was generated by adding the eco-structural data to the sine wave using the waveshaping synthesis method at double depth (ie eco-structure x 2). The generated waveform was reduced in amplitude to avoid clipping at numerous points. This waveform has an identical structure to figure 2, however those same irregularities have been enhanced (See figure 3).

The fourth tone is a sine wave that has been waveshaped using a random number generation algorithm. Unfortunately the waveform has now lost integrity in terms of its sine wave origin. There is still some form left, however it now contains constant zero-crossings, and needed to be halved in amplitude to reduce the constant clipping. It contains primarily white noise and can no longer function adequately as a pitched tone (See figure 4).

The fifth tone generated is a waveform which was created with the waveshaping synthesis method using the same eco-structure as in figure 2 and 3, however in this example the data has been scaled in time, and each point is interpolated from the current data point to the next data point. The time scale factor was x 10. The generated waveform was reduced in amplitude very slightly to avoid clipping at a couple of points. The resulting waveform has retained most of its contour, however, it has more colour and timbral variation than a sine wave. (See figure 5)

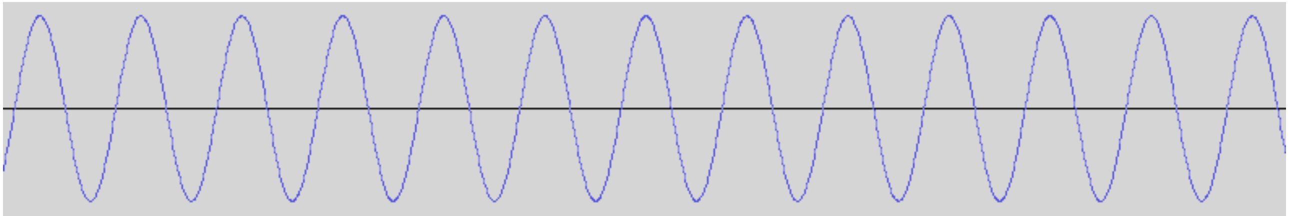

Figure 1: A sine wave

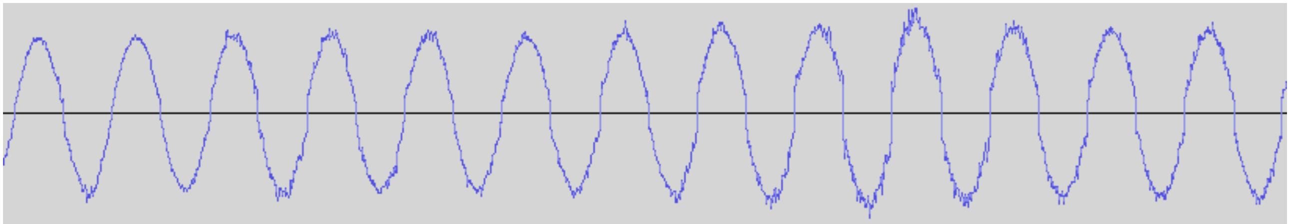

Figure 2: An eco-structure applied directly to the sine wave

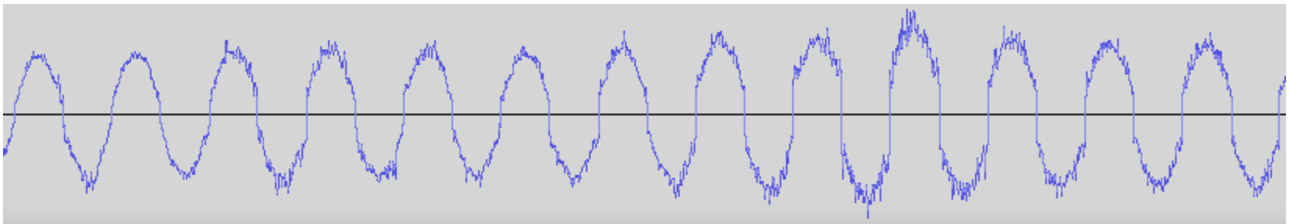

Figure 3: An eco-structure data applied directly to the sine wave at double the depth rate

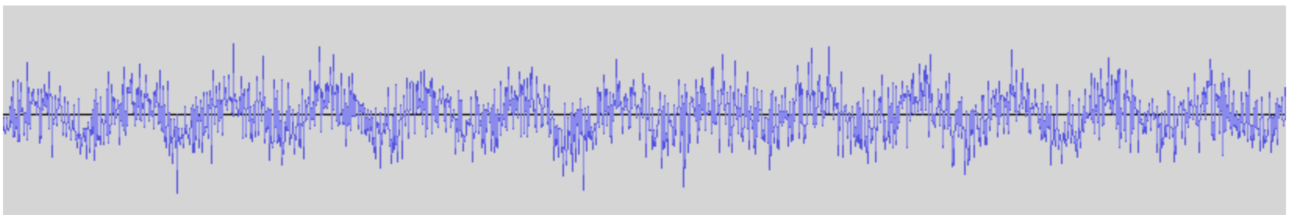

Figure 4: A random number sequence applied to a sine wave

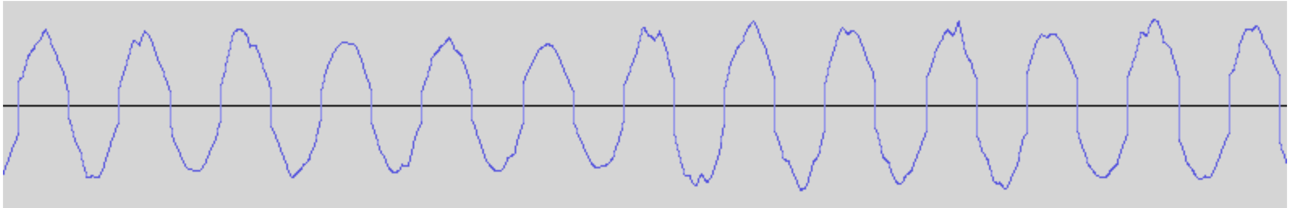

Figure 5: A stretched, interpolated eco-structure applied to the sine wave

Note: These examples can be heard at: http://www.ecostructuralism.com/database.php

There are a number of useful applications and benefits of this process. Because the structure is preserved in such a strict structure, the same tonal quality can be applied to any sine wave or tone in a precise and repeatable manner. This application allows a composer to add a degree of irregularity very easily, whereby they can build up an entire series of tones with similar or even identical tonal qualities, to use in a musical composition. As can be seen from figures 2, 3 and 5, the eco-structural process works as a good middle ground between pure sine waves and noise. It adds a certain degree of complexity and irregularity, without having to rely on some kind of random process.

These examples all deal with eco-structuralism at the microstructural level, however at the macrostructural level the same aesthetic potentials are also available. We have been experimenting with the use of structures as devices to alter the tempo of music, and to dictate the length of movements and phrases. This area is still under heavy investigation, and will be discussed further once we have more complete musical examples to work from.

8. CONCLUSION

Eco-structuralism is most easily positioned as a post-structuralist concept, in which the preservation of the structure is the most important feature of the process but the cultural factors relating to the source materials and reception context are acknowledged as significant influences on the aesthetic experience of the work. We acknowledge the inherent flaws of the analytical process, in that the natural aesthetic properties are diminished through the analytical and re-mapping process.

If there are parallels between the aesthetic appreciation of natural sounds and eco-structural music based on those sounds, as we would hope there might be, the question of at what level these relationships manifest themselves is still an open question. Is there any similarity at the level of structural recognition, expressivity, emotion evocation or representation, timbral correspondence, or some other means of transference? As we have shown, answers to these questions invoke long debated questions about the aesthetics of music which we do not claim to have resolved in the discussion, but we do hope to have acknowledged that eco-structuralism has, perhaps more than many compositional techniques, interesting aesthetic implications given its deliberate invocation of nature as a direct source of artistic inspiration.

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EXPERIMENTAL ELECTROACOUSTIC FEEDBACK SYSTEMS, THE PERFORMER AND THEIR AUDIENCE

Dr Malcolm Riddoch
Music Technology
West Australian Academy of Performing Arts
Edith Cowan University

ABSTRACT

The paper presents a phenomenological description of an experimental approach to solo improvised electroacoustic performance utilizing acoustic space, a Logic Pro environment buss array, Max/MSP and inherently unstable acoustic, electronic audio and midi feedback loops. Thematic dissolution is the musical theme following notions of indeterminacy in the composition and performance of musically organized sound. Embodied, performative engagement within acoustic space, both conceptual and practical, passive and active, is discussed in relation to experimental composition, the technological setup, the sounds themselves and the audience.

1. THEORETICAL BACKGROUND

Experimental approaches to electronic music composition and performance are as diverse as the composers who have taken on experimentalism as a possibility for their music practice[1] [22, 23]. This paper does not attempt to posit any universal definition nor genre for the term 'experimental music' but rather sets out to describe one possible method, its technological setup, compositional strategies, and the performative dynamics involved in such an approach.

This particular experimental approach has evolved from a number of phenomenologically grounded research interests centred around Pierre Schaeffer's [30] notion of acousmatic listening and electronic transformation of soundscapes; John Cage's notions of indeterminacy in composition and performance [5, 6]; Alvin Lucier's[2] use of whole acoustic spaces in music performance; and, following Pauline Oliveros [24], electroacoustic improvisation as a guided attentional process. Its medium is non-tonal, timbrally focused musically organised sound.

Phenomenological inquiry in this context, following the early Husserl and Heidegger[3], is a 'how to' rather than a 'what' - it requires a methodologically based description of 'one's own' lived experience, or musical experience in this case. An inductive rather than deductive technique, this phenomenological description attempts to open up musical possibilities by disclosing the musical phenomena themselves as they arise in the process of performance. As such, this theoretical focus is derived not from a theory about music but from a music praxis itself.

From this perspective, the analytic context for a descriptive analysis of musical performance revolves around uncovering the constantly changing, meaningful relations involved in the solo electroacoustic improvisatory practice itself. That is, the relational (intentional) processes of engagement between the performer and:

- their technical setup
- the graphic score
- the acoustic space
- the audience
- the sounds themselves

It should be noted that attentional processes are one form of intentional relation, intentionality however also encompasses meaningful relations that are not necessarily explicitly disclosed in one's attention. For example, while attending to a graphic score during performance one cannot also at the same time focus attention on the acoustic space, and yet the acoustic space remains a meaningful (intentional) context within which the performance takes place. Furthermore, practical understanding - or an embodied relation to these various aspects of musical performance - rather than rational thought processes, is prioritized in relation to the ongoing auditory perception (aesthesis) of the sounds themselves. Music in terms of both performance and listening, is here assumed to be an embodied, ongoing, temporalizing process of meaningful relations in constant flux[4].

[1] Both Pierre Schaeffer's phenomenologically influenced acousmatic approach to experimental music and John Cage's experimental notions of indeterminacy are, however, central to this experimental theme.

[2] Alvin Lucier's use of acoustic space in compositions such as *I am Sitting in a Room* and *Shelter* [19] along with my participation in the 2007 Transnational Ecologies internet performance of *Quasimodo the Great Lover* [28] and Lucier's notions of acoustic exploration [20] have particularly informed my understanding of the compositional possibilities involved here.

[3] My Doctoral specialty [26] is in the convergence and divergence of phenomenological concepts in the early works of Husserl and Heidegger. This descriptive approach is largely derived from Husserl's Logical Investigations [13] through to Ideas Book 2 [14] as well as Heideggers early transcendental phenomenology [10, 11].

[4] A more detailed discussion of this phenomenological approach is included in a paper for the forthcoming THNMF Conference 2009

2. THE PROBLEMATIC

2.1. Disclosing Performative Relations

The electroacoustic performance setup described below (see 3.1 Experimental Setup) has evolved out of a practical exploration of the composition and performance relations involved in solo electroacoustic improvisation. The experimental aim is to uncover in a practical sense those relations as they arise in the performance itself in order to then describe the phenomena and their dynamics. The compositional approach thus uses Oliveros' notion of improvisation as an attentional process [24, 31] to set up performance relations that specifically require attention to the reverberant acoustic space within which all performance and audience takes place.

The electroacoustic setup (any transducer such as a dynamic microphone) monitors the acoustic space setting up a feedback loop[5] between transducer and speakers, with electronic treatment of the sound transforming the natural soundscape of the performance space. From the performer's perspective this setup requires focused attention on the acoustic properties of that space as they transform the audio input/output over the duration of the performance. Interestingly this also includes the acoustic damping effect audience members' physical bodies have on that space as well as any ambient noise emanating from the audience itself.

In terms of the attention paid to musical structure, improvisation does not require following a more or less strictly defined set of tonal and rhythmic instructions. On the contrary it requires an openness to the sounds themselves as they occur [2] and this openness is reinforced by a composition structure that, following Cage [6], is indeterminate with respect to performance.

An acousmatic approach to the performance complements the indeterminacy of the improvisation by emphasizing the performative attention to the sounds themselves as they arise and without reference to their originating source. Acousmatic transformation of the soundscape[6] is accomplished electronically with attention to the timbral character of the mix as it evolves. This forward looking musical attention is not concerned with developing a pre-conceived theme but instead responds to the indeterminate immediacy of the initial soundscape shaped by the acoustic space. Subsequent electroacoustic inputs monitor this transformation via the speaker to electroacoustic input feedback loop and the development of the musical theme as a whole evolves out of this unpredictable and circular signal path. The indeterminate focus here is on thematic dissolution as a musical theme in itself.

2.2. Aesthetics as Aesthesis

While many experimental approaches to music have been criticized for their 'sterility' or lack of musicality, and this is perhaps especially the case with Cage's indeterminate approach to performance [18], it remains that the musical/noise outcome must primarily be a product of the compositional concepts at work rather than the composer's or performer's aesthetic choices. However, it does seem rather artificial to exclude aesthetics from a musical performance that is composed to uncover a performer's dynamic relation to music.

The performer's relation to the sounds themselves is in phenomenological terms fundamentally a process of aesthesis or straightforward sensory perception that is always accompanied by a flux of affect or feeling (pleasant, unpleasant and neutral). Rather than abrogating aesthetic choice entirely the composition structure requires a degree of attention towards the timbral qualities of the sounds themselves in order to uncover this important musical relation. The performer thus improvises the electronic mix by following what sounds 'pleasant' or 'unpleasant' within the constantly evolving feedback loop.

A focus on timbre and aesthetics also brings to light the improviser's problematic relation to their audience [1]. Focusing on the audience members' possible reception and aesthetic valuation of the performance can be a serious distraction for a performer, and improvisers have devised various means to neutralize this tendency[7]. For this experimental composition, the acousmatic transformation of the acoustic space's soundscape should be guided by the performer's aesthetic choices in response to the indeterminacy of the constantly evolving sounds. The use of the acoustic space itself also bodily involves the audience and any sounds they might make thus both problematizing and making use of the performer's dynamic relation to their listeners.

3. METHODOLOGY

3.1. Experimental Setup

A transducer (condenser, dynamic or contact microphone, electric guitar/bass and so on) monitors the acoustic space and provides the only audio signal input into a laptop computer running Apple's Logic Pro mixing environment controlled by a hardware mixer. The

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Proceedings [27]. While my primary phenomenological sources are Husserl and Heidegger the relation to music has also been informed by Lochhead [18] and Clifton [7, 8] amongst other phenomenologically influenced musicological approaches [3].

[5] Electroacoustic compositions using various forms of feedback began in the 1960's, David Tudor's 1969 *Rainforest* work being an excellent example of electronic feedback systems [29]. While the Larsen effect of runaway acoustic feedback (squealing microphones) does play a part in the current composition under discussion here, it is merely one form of feedback. I am also interested in feedback systems as a whole, including electronic, digital data, logical and practical/performative feedback and their relation to composition [4, 21].

[6] There is an interesting convergence of soundscape and acousmatic methods involved in monitoring an acoustic space during performance. The initial audio input is the soundscape of the acoustic space whereas subsequent electronic manipulation of the sound transforms the soundscape, obscuring its origins. The acousmatic output via the speakers then becomes the electroacoustic feedback input and so on.

[7] Charlie Parker for instance would often play with his back to the audience in order to concentrate on the improvisation [1].

raw mono audio input is bussed to any of six auxiliary channels, each with a set of EQ, compression and effects inserts. Each auxiliary can be bussed to any of the five others resulting in a 6x6 buss matrix (see Figure 1). In terms of the possible signal path bus combinations, this simple auxiliary array offers 2^{30} or around 1 billion choices for routing the digital audio signal internally[8].

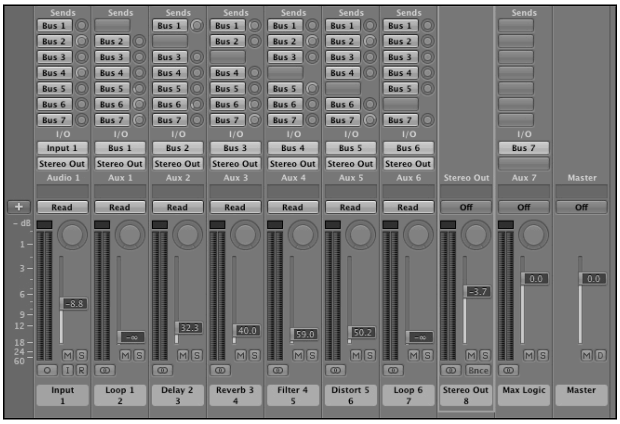

Figure 1. A simple 6x6 auxiliary buss array in Logic Pro offers 2^{30} possible combinations for mixing.

Two audio channels mixed from the input channel or any auxiliary are bussed to a Max/MSP patch for sinusoidal analysis. The raw waveform data outputs are scaled and variable speed limited to produce 24 independent MIDI controllers that are mapped back onto various insert parameters across the Logic auxiliary channels (see Figure 2). Dynamic insert parameter control is thus automated by the audio signal itself.

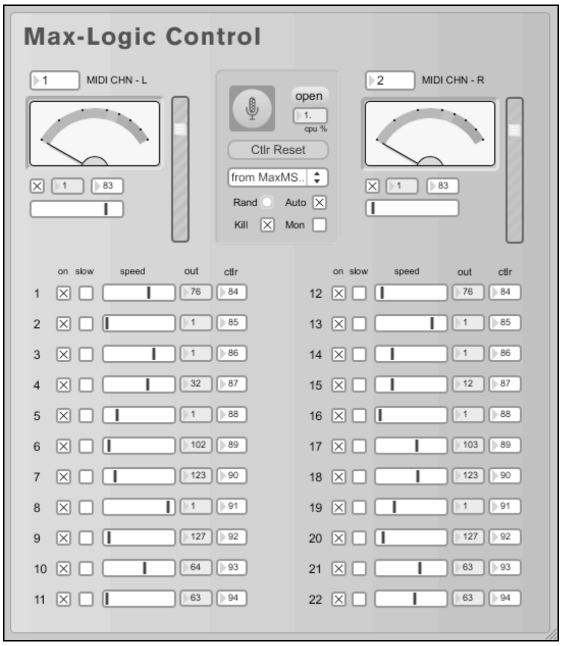

Figure 2. Max/MSP sinusoidal analysis to MIDI controller patch.

[8]Each auxiliary channel has 5 busses. Assuming each buss is either on or off there are 2^5 or 32 possible combinations per auxiliary, or 2^{30} = 1073741824 routing paths across all 6 channels.

Sidechain compression is used across all auxiliaries to help automate the mix. The improvisation largely consists of riding the faders and EQ settings, and navigating through the buss structure, setting up signal path loops and controlling acoustic and electronic feedback.

The technical setup is arranged for maximum sensitivity to the acoustic space, transforming the electroacoustic input that in turn drives the parameter control and provides the output and raw audio input signal for ongoing improvised mixing choices in response to that reverberant acoustic space. Complexity in the auxiliary buss array allows a high degree of freedom in the improvisation and provides the technological potential for navigating between electroacoustic serendipity and chaos.

The live performance audio input is recorded at 24bit 48kHz (effectively a field recording) along with all automation in Logic and provides the raw material for further studio editing and mastering.

3.2. Composition Structure

The electroacoustic technology and its signal paths define the limits and potential of the compositional structure. Use of a graphic score (see Figure 3) and performance instructions showing possible buss patterns and other interactions over time allows for a structural approach to the improvisation. The specific properties of any acoustic space (including microphone and speaker placement within it, audience interaction and so on), uniquely define the acoustic response of the feedback system as a whole such that no two performances of the identical score and technical setup can be the same.

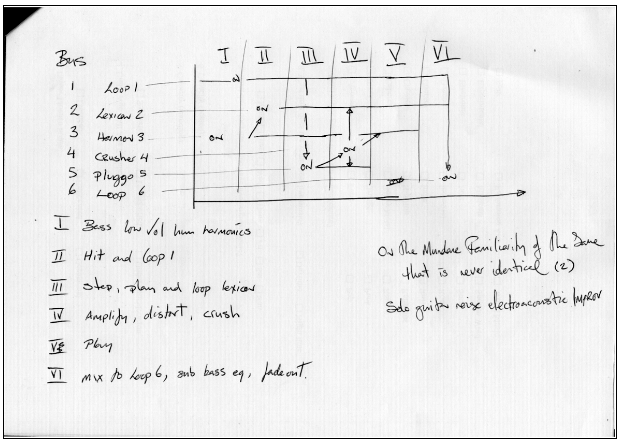

Figure 3. Early draft of graphic score and instruction set for June 2009 performance.

Likewise, the fragile complexity of the auxiliary buss connections, vulnerable to escalating electronic feedback that then drives electroacoustic feedback and dynamically changes each channel's insert parameters, is akin to wandering through a compositional forest of one billion trees at night without a compass in a storm[9]. This

[9]After Heidegger [12], *Holzwege*, or forest paths, is a metaphor for a phenomenological method of inquiry. Essentially exploratory it rejects

compositional indeterminacy is explicitly built into the technical setup to accentuate performative uncertainty. Whilst various initial buss and insert conditions can be tested in the studio the resultant graphic score acts merely as a general guide to possible pathways through an otherwise constantly evolving soundscape and its electronic acousmatic transformation.

4. PERFORMANCE RESULTS

The composition and technical setup described above has been developed over a year's practical research. Each performance and studio experiment has developed not only the electronic techniques for the acousmatic transformation of the soundscape within an acoustic space but also the attentional awareness of the performative relations that the composition is intended to bring into play[10]. This ongoing performative development, an experimental form of practical music research, has in turn aided in the further development of my theoretical interests in a phenomenological investigation of musically organized sound.

Together, theoria and praxis are both necessary elements of phenomenological analysis where the phenomena in question can only be disclosed firstly via demonstration and then description. The experimental performance approach described in this paper is just such a practical demonstration of an ongoing music research project. The following sections are preliminary reflections on the performance results so far.

4.1. The Technological Setup

The electronic music technology used forms the practical background context for the electroacoustic performance, and an attention towards the embodied, tactile nature of performance[11] within an acoustic space has highlighted several spatial relations in that performativity.

Electroacoustic inputs via a contact, condensor or dynamic microphone, or an electric guitar/bass resonating in the acoustic space provide a direct, performative connection with that space. It is this basic electroacoustic feedback loop between the transducer input and amplified output via the whole acoustic space that provides the context for all other interactions with the audience, the electronic setup and the sounds themselves. This holistic attention to the spatial context within which the performance takes place constitutes the basis of my compositional approach[12] in that all other attentional relations are disclosed in relation to that acoustic space as a whole.

This attention to embodiment and space has emphasized a commonly reported technical problem with laptop computer performance: The use of a mouse pointer in a graphic user interface is very limiting and the inclusion of a hardware interface (in this case a Euphonix MC Mix) has greatly expanded the potential for control of both the electroacoustic and internal electronic feedback loops while allowing for more expressive treatment of the timbral qualities of the sound.

Navigating the send busses and volume faders, insert parameters such as EQ notches, compression gain and ratio, and various static effect as well as Max/MSP settings allows for a diverse range of improvisational choices throughout the performance. Due to the unpredictable, chaotic nature of the positive and negative feedback loops generated, these choices are generally driven in response to the sounds produced by the technical setup rather than a preconceived aesthetic. Any thematic development, such as resetting the busses to the next phase in the graphic score, is constantly destroyed by this inherent indeterminacy. Nonetheless - and in common with much experimental, improvised electroacoustic music as well as arguably athematic serialism - constant thematic dissolution does produce a recognizable musical form often experienced as noise, depending on one's aesthetics. Thematic dissolution is in this sense both a musical theme and an indeterminate composition concern built into the technical setup itself. It demands an openness to both the sounds themselves and the improvisation in response to those sounds, and emphasizes the dynamic temporal processes involved in the performance as a whole.

Use of Max/MSP to automate the control of insert parameters in response to the changing electroacoustic waveform adds a strong element of indeterminacy and constant change to the evolution of the sound and also helps break up feedback loops. The overall MIDI output is noticeably sensitive to the amplitude of both input audio channels into Max/MSP, each of which can be manually adjusted via the Logic busses and in the Max patch itself. Making use of three independent sinusoidal analysis patches to transform digital audio data into 24 unique waveform data streams allows for a significant degree of complexity in the Logic parameter automation. Multiple parameters can be controlled by one MIDI controller, including any insert, panning/spatialization, send buss level and so on. However, balancing CPU usage and MIDI buffer overruns with the controller data rate defines the technical limit of that complexity.

The rate of MIDI controller data sent to Logic Pro from each of the 24 controllers can be individually varied

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the notion of any absolute ground or starting point for an analysis of the meaningful relations of lived experience, in this case the performative relations of electroacoustic improvisation. One chooses a path and hears where it leads.

[10] A set of performance (field) recordings *(Variations on Acoustic Feedback)* are due for mastering and release on the Slow Release Music Label in late 2010 (http://slowrelease.waapamusic.com). See also http://malcolmriddoch.com for streaming audio examples.

[11] Embodiment and spatiality are a common phenomenological theme. For a discussion of embodiment from a musical perspective see for example Corness [9].

[12] Along with Lucier the site specific, environmental works of Australian acoustic composer Alan Lamb [16] have also influenced my approach with their sensitivity to natural and human soundscapes, and auditory evocation of the spatial and temporal dimensions of place.

from 5 messages per second to one every 3 minutes. At fast rates the parameter changes can result in very densely textured audio output while slower rates tend to produce more stable responses punctuated by sudden changes. In the initial default state all MIDI controllers are on and set at the same (fast) rate producing a synchronized effect in the parameter automation and resultant audio. The rate can be randomized for each controller and automatically reset at random intervals resulting in asynchronous changes to the insert parameterization and a perceptibly more chaotic audio response that in turn produces a wider range of dynamics in the MIDI controller outputs (see Figure 4).

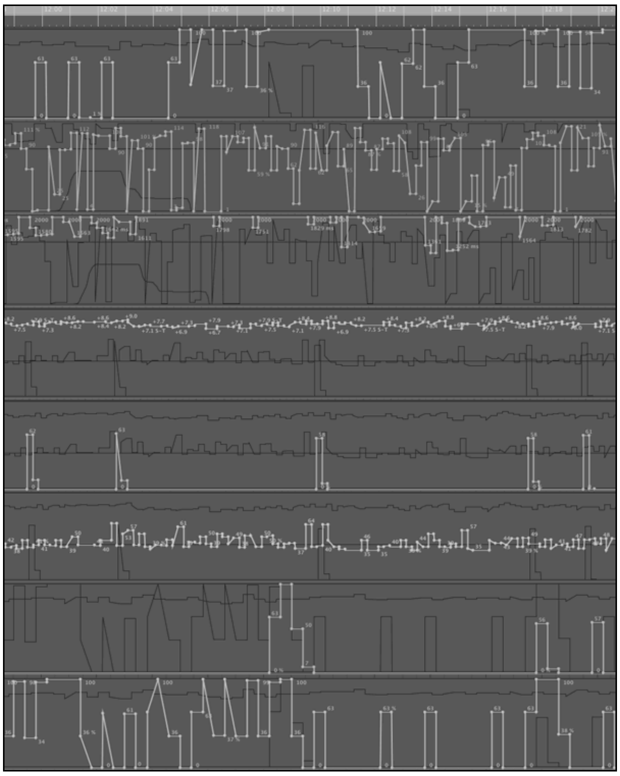

Figure 4. Photoshop composite of eight Logic Pro auxiliary tracks showing Max/MSP MIDI controller automation data over approximately 20 seconds. Recorded live at Kurongkurl Katitjin Gallery, Edith Cowan University, 21 May 2010.

The nonlinear dynamics of these various feedback systems - the basic electroacoustic loop, manifold electronic buss loops and 24 Max/MSP audio to MIDI loops - all combine and interact to produce an unpredictably chaotic yet technologically structured and thus musically organized outcome. The positive and negative feedback loops involved in this compositional setup typically produce a-periodic oscillations, abrupt changes from one more or less stable state to another, stable and unstable chaotic oscillations accompanied by sudden transient bifurcations and runaway self-reinforcing crescendos terminated by limit cycles or parameter changes. This technologically constrained, cyclically chaotic feedback system gives form to the auditory context within which all improvisation and attempts at compositional control take place.

4.2. The Graphic Score

As a set of mnemonics for operating the technological setup the graphic score aids in setting up the initial buss conditions for each phase of the performance. However, due to the dynamically unpredictable nature of any particular acoustic space and the feedback sensitivity of the electronics, while these initial buss states can be explored and noted down beforehand in the studio they can only serve as a guide during the performance itself. The auditory outcome can be radically different for the same buss structure where small differences in parameter controls can propagate rapidly through the various feedback loops.

4.3. The Audience

While an audience can often be a necessary distraction for improvisation, I have found that making the audience an object of the composition by including their interactions within the acoustic space adds a useful dimension to the performance dynamic. For example, the performance problems associated with anticipating an audience's aesthetic response to the improvised music, often viewed as a distraction by improvisers, seem to be attenuated. Instead of ignoring or shutting out the audience they become an integral part of the whole musical process. The acoustic space along with everything and everyone in it has become the musical instrument. Microphone placement can help make this relation explicit to the audience members themselves such as for instance aiming a shotgun microphone at an auditorium's acoustic 'sweet spot', quite often a few rows back from the centre, front seats.

The use of a 'black box' laptop computer can present problems for some audience members due to the relative lack of performative feedback. While a hardware interface for controlling a computer allows for a much more tactile approach to the performance it also aids in connecting the performance actions with musical results, an important aspect of audience engagement with and appreciation of computer music performance[13]. Likewise, the projection of the graphic score acts as an extension of this performative communication and assists in audience engagement with the work.

While passive audiences have an effect on the acoustic properties of the performance space simply by virtue of their body mass, thus altering the electroacoustic transducer input, they can also produce sounds in response to the performance (coughing, shuffling of feet and so on). With this in mind, and contrary to usual concert protocol, audience engagement is sometimes encouraged in the sense of inviting any sonic interventions audience members might come up with in response to their sonic environment. This adds an essentially indeterminate, discontinuous audio input into the electroacoustic and MIDI feedback loops that assists in breaking up runaway electronic and acoustic feedback

[13]For a discussion of this problem and possible solutions see for example Garth Paine on standardizing interface guidelines [25].

as well as contributing to the timbral complexity of the mix.

Giving a compositional context to these performative relations to the audience, as opposed to simply ignoring them while performing, does seem to accentuate these positive aspects for performance. The audience now has a use value for the composition and performance of the musical work itself beyond being there to merely receive, listen and critique.

4.4. The Sounds Themselves

Musically organised sound can be fascinating, both for audiences and performers alike. Forgetting oneself and becoming absorbed in the sounds themselves is perhaps one of the main pleasures and primary motivations for listening to music. I have always been fascinated by the collective fascination and focussed attention displayed by audiences listening to and watching musical performance.

Musical fascination is posited here as a mode of aesthesis in the sense of an absorption in the ongoing auditory perception of the sounds themselves as they arise and fall away. Being captivated 'in the moment', for performers and audience alike, could be said to be one general indicator of a successful performance. From the perspective of the indeterminate electroacoustic composition under discussion, aesthetic fascination can take the form of an absorption in timbral affect - the pleasant surprise associated with serendipitous mixing choices coinciding with the Max/MSP parameter automation and acoustic/electronic feedback. Following the aesthetics of the sounds themselves and allowing the acoustic space to dictate the resonances and evolution of the work as a whole comprises the overall context within which all other interactions take place.

However, for this performer, aesthetic absorption in the sounds as they are heard is an attentional process that is subject to constant dissolution due to the simple fact that the sounds themselves are just one of the relations of sense involved in the performance. One's attention also constantly deals with compositional priorities, the control of runaway feedback, and the demands of a complex and inherently fragile technical setup. I can only assume that aspects of this relational process are more or less common to all forms of music performance, acoustic and electroacoustic, determinate and indeterminate, from dot notation through to open improvisation. The musical sound provides the ongoing background context within which one deals with the composition, the instruments and the audience. Absorption in the sounds themselves remains an ongoing, open possibility.

Making this dynamic relational complex an explicit object of the composition does seem to aid in separating out the various attentional processes. While absorption in the sounds themselves also relies on becoming increasingly competent with the instrumentation and the composition, an awareness of how these processes interact could perhaps assist in being open for the moment one's attention might become absorbed.

5. CONCLUSIONS

Experimental music composition and performance as a disclosure of the sounds themselves in their lived, relational, spatial and embodied context would seem to be a complementary practical methodology for phenomenological music research. Practical awareness of the attentional processes involved in performance is enhanced by making these processes the object of the experimental composition, and the results of the performance can be used to further investigate the phenomenal relations at play.

As regards this preliminary descriptive investigation, the performance of improvised, electroacoustic music as a whole is a dynamic process of change in the constant arising and dissolution of musical attention. It is a play of attention to composition, technology and audience within the reverberant acoustic space of the sounds themselves - and all of these intentional relations are subject to constant dissolution as a flux of attentional processes for the duration of the performance.

The sounds themselves remain constant however as either the background auditory perception (also a mode of aesthesis) informing the practice or as the foreground object of aesthetically absorbed attention. In other words, one can attend to the composition, the technical setup or the audience but only within the acoustic space: The sounds themselves are the auditory context giving meaning to and ultimately guiding these performative relations. From this phenomenological perspective, the performance of musically organised sound always has an embodied, performative, lived context and the musical work as a whole is a complex network of meaningful musical relations in constant flux.

Further research into the dynamics of this relational flux is proposed in terms of the phenomenological structure of lived time or temporality (*Zeitlichkeit*[14]). This notion of time is characterized by its circular logic and is the primary logical feedback concept informing my experimental music approach. A compositional structure building on the current paper's provisional investigation into the intentional (attentional) processes involved in musical performance would require methods for the disclosure of this circular temporal structure that links musical perception, affect and practice together. 'Openness' to the sounds themselves and 'thematic dissolution' as a compositional theme are two phenomenologically derived methodological concepts under consideration for the further development of the experimental approach outlined in this paper.

[14]Zeitlichkeit is a Husserlian term for the dynamic structure of intentionality. Also termed originary time it is a basic concept for both Husserl's phenomenology of inner time consciousness [15] as well as Heidegger's early transcendental phenomenology [10, 11].

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COMPOSING “ IN TRANSIT”

Michael Spicer

Singapore Polytechnic/
Monash University Conservatorium

ABSTRACT

“In Transit” is a fixed form electro acoustic piece. It combines of a number of short improvisations performed on an instrument created by the composer using the ChucK programming environment. It enables the performer to create sequences of notes that display the characteristics of various probability distributions. The performer has macro level control of the output by adjusting parameters that control the algorithms, in real time. The improvisations are imported into a Digital Audio Workstation where they are edited and processed with various signal processors before being assembled to create the finished piece. The assembly makes use of a “bottom up” approach. There is no clear idea as to how the piece will be, the final form emerges from the way the composer combines the improvisations. The composer works largely intuitively, making use of high-level concepts such as progression, continuity and contrast as a framework to help make compositional decisions.

1. INTRODUCTION

“In Transit” is a fixed form stereo playback electro acoustic piece. It was created using a combination of ChucK, and Logic Pro. All sounds are produced with physical modeling synthesizers, but the timbres have been significantly transformed by a variety of signal processing techniques. The piece is predominantly organized around timbre and texture, and (mostly) does not exhibit a clearly articulated rhythmic pulse. A characteristic feature of the piece is the use of diffuse clouds of notes that fade in and out, which was the only element of the piece that was decided upon when the composition of the piece was begun. The overall form grew out of the composition process, but effort was made to make sure the piece had a sense of progression, as if the listener was on a leisurely journey, hence the name “In Transit”.

The impetus for creating this piece came from a demonstration of the “Probability Jammer” in a music class. Each student was running “Probability Jammer” on his or her laptop and they all played with it through the laptop speakers. The class was divided up into groups, and students were directed to adjust the parameters in particular ways, “conducted” by the composer. This created an interesting cloud of notes in the room that changed as the students performed. This effect was the only preconceived characteristic that the composer set out to achieve in the final form of this piece.

2. COMPOSITIONAL APPROACH

“In Transit” is part of a collection of pieces that are created using a “bottom up” compositional methodology that attempts to apply some of the approaches the composer has successfully used in popular music to an electro acoustic context. In particular, there is the intention to include an element of improvised performance as the way of creating musical material, which is then further refined, out of real time. The piece is constructed in three distinct phases.

1. Create Real Time Improvisations
2. Apply Processing and Editing
3. Assembly/Mix

To use an analogy of a child building a plastic model kit (such as a plane/car/ship), the first phase involves creating the basic components (done by the model manufacturer), the second phase would be painting the parts, and the third phase, assembly. The big difference between the model building process and the compositional process is that the final form of that model is known from the beginning, while in this composition, the final form emerges in the assembly process, and is not apparent until the end. In that respect, it is like taking a collection of Lego bricks, and, without any preconceptions about what to make, putting pieces together randomly for a while, then assessing the situation to see if the assembly suggests any particular thing, then modifying this to refine it.

2.1. Phase 1 – Real Time Improvisations

In this piece, the basic building blocks were fourteen short solo (unaccompanied) improvisations performed on an instrument that the composer created with the ChucK programming language, called “Probability Jammer”. This instrument makes use of two probability distribution generators to control the pitch and duration of notes that are produced using one of the STK physical modelling synthesizers [1]. All of the STK instruments supplied with ChucK are available for use with the instrument. “Probability Jammer” has a very simple user interface, shown in figure 1, implemented using the MAUI widgets, part of the MiniAudicle ChucK development environment. Each onscreen fader can also be controlled via a MIDI fader box, which effectively allows all parameters to be altered simultaneously.

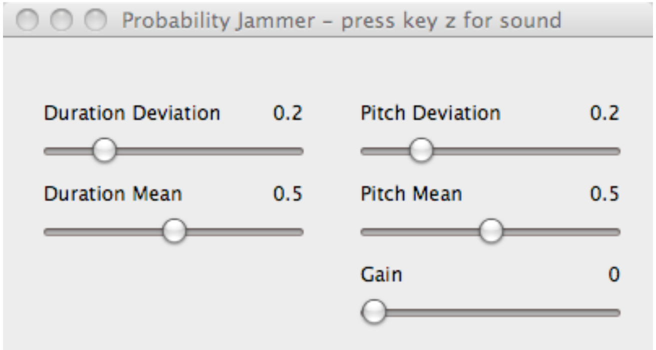

Figure 1. “Probability Jammer” user interface.

An example of the output of one of the probability generator functions (the Gaussian) with different settings is shown in figures 2, 3 and 4. The left hand window is a plot of the output produced when the generator is run 100,000 times without changing the parameters. The right hand window displays the corresponding (normalized) probability distribution function, and the relationship between changes in the parameter settings and the output produced is quite apparent.

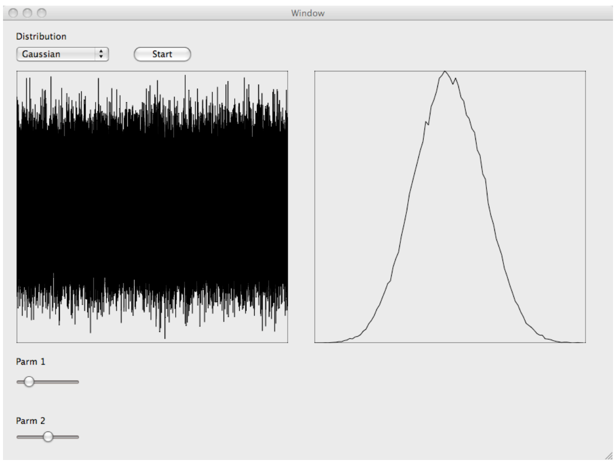

Figure 2. Output of the Gaussian generator, with its probability distribution for 100,000 samples. The mean is 0.5 and deviation is 0.2.

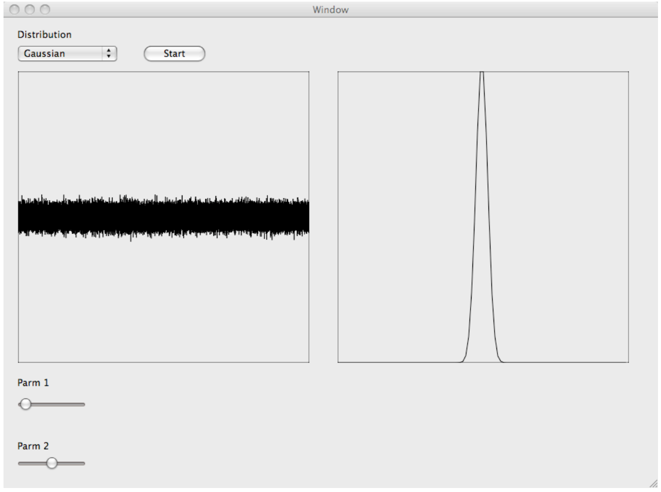

Figure 3. Output of the Gaussian generator, with its probability distribution for 100,000 samples. The mean is still 0.5, but the deviation is reduced, producing a series of outputs that are closer to the mean.

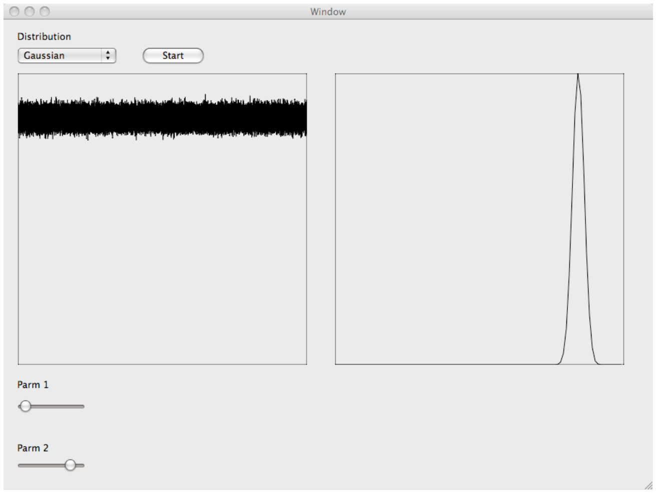

Figure 4. Output of the Gaussian generator, with its probability distribution for 100,000 samples. The mean has been raised, while the deviation has been kept the same as figure 3. Now the outputs are clustered around the new (higher) mean.

In order to perform with “Probability Jammer”, the composer needs to specify the type of probability distributions to be applied to pitch and duration, select the synthesizer (all specified using the ChucK language), and initialise their controlling parameters. Various probability distributions, taken from the standard literature [2,3,5], can be applied to the pitch and duration, such as Gaussian, Linear, Exponential and Triangle probability distributions (Settings for using Gaussian are shown in figure 1). One other improvisation was made with another ChucK instrument that is a variation of “Probability Jammer”. This instrument is optimized for making multilayered drone like textures. It makes use of a Gaussian probability distribution to choose pitches that are at harmonic frequencies of a note specified by the user, via a keyboard, using a number of STK synthesizers.

Different strategies were employed by the composer to create the different improvisations that form the raw material for this piece. In a few improvisations, there were no changes in the controls during the recording phase. Once the instrument settings were producing a distinctive output that the composer found interesting, the audio was recorded for around thirty seconds. One example of this approach is the improvisation used at the very beginning of the piece. It makes use of a Gaussian distribution to control the pitch, with the mean pitch set quite low and a medium deviation around this pitch. The duration is set so as to produce a constant, fast, note rate. As these parameters do not change, all of the notes generated exhibit these characteristics. Most of the improvisations, such as the solo melodic line in the middle of the piece, were created by initializing the system to a configuration that the composer felt was a good starting point, and then performing the improvisation by adjusting the probability distribution parameters while the part was being recorded. In this situation, the composer was usually thinking in terms of melodic line, aiming at creating a recording with a degree of variation in the note rate and the pitch. There was an attempt to create a distinct pitch contour, with some rhythmic variation.

2.2. Phase 2 – Processing and Editing

The second phase of the composition process involves "dressing up" the timbre of the raw improvisations (which sound very raw indeed) to create a basic palate with which to assemble the piece. The recordings of the ChucK improvisations were imported into Logic Pro8 and signal processing was applied to each part so as to accentuate an aspect of its character that appealed to the composer. The aim was to create a collection of distinct musical "gestures" that would be recognizable, even after undergoing various transformations, as these will be the elements that provide coherence and can help a listener make sense of the piece.

All of the standard modern signals processing options, such as equalisation, reverb, compression etc, were utilized as seemed appropriate, during this phase of production. It is worth noting that a large part of the characteristic surface "sound" of the piece came from extensive use of the "EnVerb" plug in (a combination of a reverb and an envelope shaper), the Rotary Speaker simulator, as well as various types of delay and distortion. Offline Pitch Shifting was applied to some of the audio files, to create some of the low pitched parts. Additionally, in order to enhance the "sound cloud" effect that was apparent in some of the improvisations, those recordings were duplicated, cut into sections and reordered, and layered with some timing offsets. This resulted in a more diffuse cloud of notes with the same overall pitch characteristics.

2.3. Phase 3 – Assembly and Mix

Once the palate of parts was in place, the piece was assembled. This took place over a period of one month. It was done using a trial and error process involving experimenting with different combinations of parts so as to create a distinct character that appealed to the composer. It was important to the composer that the final form of the piece exhibited a certain clarity/transparency in its overall sound. To help achieve this, experiments creating different textural layers, with various degrees of timbral contrast, were undertaken. After some time, nine distinct textural layers and four distinct sections emerged:

1. High and low organ like flourishes over the multilayer drone.
2. Swirling "cloud like" textures.
3. A melodic section making use of the "bowed" STK instrument.
4. A noise/percussion section.

In this phase of the construction, the texture and timbre of large groups of notes were the main concern, rather than the details of the individual notes. Pitch is only organized in terms of predominant register (High, Medium, Low).

The primary concern was to achieve a sense of cohesion and progression through the duration of the piece, with a convincing musical continuity (with appropriate balance between "flow" and "break"). In its final form, the piece starts quite lively and progress towards an (anti) climax, where it virtually stops, and then returns to some state similar to the beginning (a variation of a traditional ternary form). The final form is clearly seen in the screen shot of the arrange page of Logic Pro, shown in figure 5.

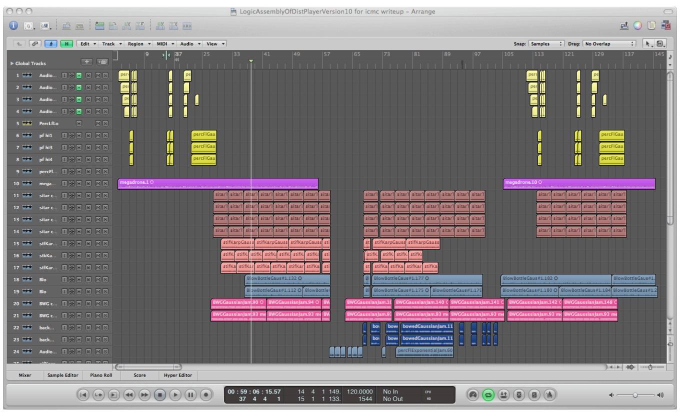

Figure 5. Logic Arrange page, indicating the overall structure of the piece.

3. HISTORICAL CONTEXT

"In Transit" is part of a project that attempts to apply, in an electro acoustic context, some of the processes that the composer utilized working with rock/folk/jazz groups (and recording sessions for TV and film) in the 1980s. Central to this approach was that players made use of distinct strategies to come up with their own part, rather than playing a set "arrangement". The arrangement emerged spontaneously, in real time. In that situation, the strategies were often "rules of thumb" for creating common textural elements. An example would be the various different approaches used to create the idiomatic rock/jazz/ballade/country bass lines. Approaches for these could be (amongst many others):

- rock - play the root of the chord in quavers.
- jazz - play a "walking bass" making sure to clearly emphasise the chord tones.
- ballade - play the root of the chord dotted crotchet-quaver pattern.
- country – play the root and fifth of the chord in minimums.

Similar idiomatic approaches were applied to the creation of "comping" patterns, pads, arpeggio parts and counter melodies etc. Often, this approach is moderated (often by a producer) either in rehearsal, while the parts are being recorded (especially in a multitrack recording situation) or after the performance was recorded. Mixing, signal processing and editing techniques, such as copying/cutting and pasting/splicing, have been utilized extensively to modify recorded improvised performances, since the mid 1960s. A well-known example is "Bitches Brew" by Miles Davis, where the raw recordings of the musicians were heavily edited to create the final record. (Ironically, for this project, "Bitches Brew" was influenced by the work of the Musique Concrete composers.)

The process used to create "In Transit" is an obvious descendent of the above process. The "rules of thumb" are replaced by the distinct improvisation strategies used to create performances with the "Probability Jammer" (directly inspired by Xenakis), and the finished composition emerges through choices made by the composer in the assembly process, making use of extensive studio production techniques.

4. CONCLUSION

In this piece, the composer has made use of a compositional process that attempts to create an electro acoustic piece that combines the elements the spontaneity of an improvised performance with the careful consideration of a pre-composed piece. The process provides a lot of opportunities to create interesting musical results through the serendipitous juxtaposition and superposition of material. The approach also enables the possibility of musical decision making skills developed in other musical genres to be applied in an electro acoustic context, which may be considered, by some people, as a desirable attribute.

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Mobile Scores and Click-Tracks: Teaching Old Dogs

Lindsay Vickery
Western Australian Academy of Performing Arts, Edith Cowan University

ABSTRACT

This paper reconsiders the paper score as a medium for presentation of mobile score works. The precedents leading to the development of mobile form in music are discussed. The form and modes of realisation of a range of works by Earle Brown, Karlheinz Stockhausen, Iannis Xenakis, John Zorn, Mauricio Kagel, Charles Ives and Denis Smalley are examined. The potential for computers to provide a more 'natural' medium for mobile scores is explored.

A number of computer-based solutions to the realisation of mobile scores are proposed in regard to: the single page mobile score, the multi-page mobile score, the mobile graphical score, the polytempo score and works that include pre-recorded sound and/or live electronics. Solutions including the on-screen scrolling score, the on-screen timer, the computer controlled click-track and networked multiple computers are proposed. The potential to control musical parameters such as formal structure, tempo, meter and dynamics are explored, as well as the ability to represent "free" pitch and rhythm.

1. INTRODUCTION

In the 1950s a concerted effort was made in some quarters to liberate the music score from the manacles of left-right/up-down orientation. The idea evolved, both in music and across a range of art forms in the mid-twentieth century, all sharing a common impetus to generate the opportunity for multiple readings defined by the individual.

Zizek claims that, as developments in ideology and formal innovation are interlocked, ideology and technology also evolve in parallel. He argues that

> *old artistic forms pushing against their own boundaries and using procedures which, at least from our retrospective view, seem to point towards a new technology* [1].

The mid-century saw a sudden abundance of ideas pushing against their own boundaries and pointing exploring towards a new paradigm of openness and mobility in art works. The following table charts these developments across the arts and technology.

1919	*The Magnetic Fields* by Andre Breton and Philippe Soupault explores "automatism" in poetry, seeking *'to express the actual functioning of thought'* [2].
1931	Alexander Calder creates his first sculptural "mobile" *Feathers* [3].
1945	Vannevar Bush proposes the *Memex*: a method of organizing data "as we may think" [4].
1952	Earle Brown composes *December 1952*, a graphical score capable of performance in any orientation [5].
1953	Morton Feldman composes *Intermission 6,* a score allowing the performer(s) to choose the order of the musical events [6].
1959	Iannis Xenakis composes *Duel* for two orchestras introducing the use of game theory to calculate possible musical outcomes [7].
1961	Publication of Raymond Queneau's *Cent mille milliards de poèmes* (Hundred Thousand Billion Poems), a compendium (and "writing machine" for generating) 10^{14} possible "mobile" sonnets [8].
1963	• Theodore Nelson creates the term "hypertext" to describe a system of linking related texts together in the digital medium [9]. • Umberto Eco publishes the first major theoretical text on the field *Opera Aperta* (The Open Work) [10]. • Alain Robbe-Grillet *Pour un Nouveau Roman* (Towards a New Novel), espouses disjunctions in time, place and point of view as a method of breaking down the dominance of the omniscient narrator. [11]. • The nonlinear structure of Federico Fellini's film *8 ½* [12] together with Eco's work inspires the formation and experimentations of Gruppo '63 [13].
1966	Peter Handke creates his first 'speak-in' (Sprechstücke) *Offending the Audience* – a collage of "found" words [14].
1967	Gordon Mumma explores the concept of interactive electronics in Hornpipe, a work capable of 'semi-automatic response to the sounds generated by the performer' [15].
1969	The first Interactive installation *Glowflow* is created by Myron Krueger [16].

Table 1. A timeline of textual mobility in the Arts.

The musical developments towards mobility of the score pioneered by Brown and Feldman quickly spread to the European Avant Garde and elsewhere [17]. However there were significant obstacles to the development of textual "mobility" in notated music created by its reliance on the printed-paper score. Crucially, the space-inefficient paper-score imposed upon composers an inverse relationship between the ease of mobility and the amount of information that could be provided for performer.

French "Oulipo" [18] author Raymond Queneau created a solution (for poets) in his publication *Cent mille milliards de poèmes* [19] by printing ten sonnets, in which each of the 14 lines is printed on a separate strip of paper. The strips can be arranged in any order, resulting in the potential for producing 10^{14} possible 14-line sonnets. Despite the contention of commentators such as Espen Aarseth that such *'variety and ingenuity of devices'* show *'that paper can hold its own against the computer as a technology'* [20], it is worth noting that, when searching on the internet for Queneau's *Cent Mille Milliards*, 5 of the first 10 results are hypertext realisations of the work[1].

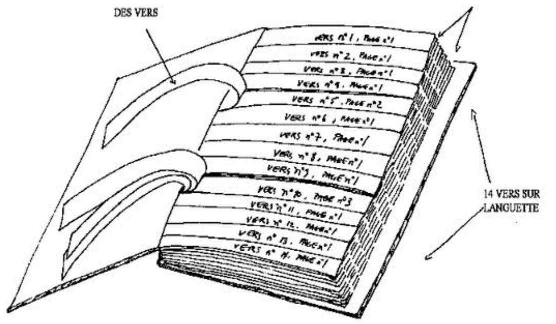

Figure 2: Raymond Queneau's *Cent mille milliards de poèmes*, Image: [21]

Indeed, the computer-based hypertextual medium, while perhaps less idiosyncratic, plainly provides a more, "natural" vehicle for Queneau's project than, again in the words of Zizek, '*the old forms endeavoured to render by means of their "excessive" experiments'* [1].

2. MOBILITY IN THE MUSICAL SCORE: FORMS AND REALISATIONS

In the mobile score, the final ordering and distribution of notated musical events is deferred by the composer until the performance. In such works

> *the instrumentalist's freedom is a function of the "narrative" structure of the piece, which allows him to "mount" the sequence of musical units in the order he chooses.* [22]

Composers have explored this approach for a variety of reasons. According to Earle Brown this strategy provided a greater level of *"spontaneity, direct spontaneous action, and more spontaneity in the compositional process"* [23], allowing *"the performer to share directly with the composer in the construction of the music"* [24]. Stockhausen's earliest mobile structure works, such as *Klavierstück XI* (1956) and *Zyklus* (1959) reflected his interest in representing the aleatoric nature of the structure of sound itself. Later "moment" works such as *Kontakte* (1958-60), *Momente* (1958-60) and *Mixtur* (1964) sought to explicitly avoid traditional musical narrative structure: *"The piece tells no story. Every moment exists for itself"* [25].

Composers such as Xenakis and Zorn have used game structures to draw on mobile form's "field of possibilities" to create tension. In Xenakis' *Duel*, the composer employs game structure to outline 19 tactics of interaction between two orchestras performing notated music. In contrast, Zorn's game pieces are "meta-compositions" that *'deal with form, not with content, with relationships, not with sound ... The improvisers on the stage (are) themselves the sound'* [26]. In both cases, the subject of the work is the inherent drama in the "playing out" of the rules. As the dubious attribution to Sartre says '*everything is complicated by the presence of the opposing team*'.

Another approach, Graphic notation, employed in some of the compositions of Earle Brown, Mauricio Kagel, Roman Haubenstock-Ramati and Sylvano Bussotti, provides a range of possible forms of mobility to the score. Firstly the symbols themselves may be, to greater and lesser degrees, asemic, that is, without semantic content. Their deviation from musical notational conventions points towards meaning that is more "open" to interpretation. Secondly, the avoidance of traditional notational conventions may also imply the freedom for the performer to move around the page in a more interrogative fashion.

> *Composers who work with such notation, where the distinction between symbol and drawing is blurred, hope that it may excite the performer's imagination* [27].

Another form of mobile score comes into being as a result of the compositional technique called polytemporality. First outlined by Henry Cowell in the 1930s [28], polytemporal works feature two or more musical elements moving at different tempi in such a way that they become perceptually distinct. Although some examples of this technique, such as Charles Ives *Symphony No. 4* (1910-16), are notated within a single score [29], they commonly employ multiple conductors or require, as suggested in the score of Xenakis *Persephassa* (1969), coordination via multiple metronomes [30].

Paradoxically, the final example revolves around the tension created by the immobility of the paper score when in combination with pre-recorded sound.

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1 http://x42.com/active/queneau.html, http://www.uni-mannheim.de/users/bibsplit/nink/test/sonnets.html, http://www.bevrowe.info/Poems/QueneauRandom.htm, http://www.smullyan.org/smulloni/queneau/, http://userpage.fu-berlin.de/~cantsin/permutations/queneau/poemes/poemes.cgi

Typically, scored works for "instrument and tape" generate problems for the live performer because of the friction between the intangibility of the pre-recorded sound and the fixity of the notated score. Even when the score is not nonlinear, for example in Bruno Maderna's *Musica su due Dimensioni* (1952) [31], the synchronization of the score and tape components provides a challenge both to the composer and the performer.

The models and examples given cover a range of modes of realization including live performers with and without electronics. In some cases, the implementation of these works in a computer-based hypertextual medium may provide a more "natural" vehicle for their performance by:

- creating a more practical, pragmatic medium for presenting information to the performer;
- preventing performers from preparing a fixed order of the work's materials;
- allowing the choice of nonlinear materials based on aleatoric or other procedures;
- reducing the need for unnecessary cues that create a non-musical distraction to the performers and/or the performance.

3. COMPUTER-BASED SOLUTIONS TO THE REALISATION OF MOBILE SCORES

3.1. The Single page mobile score

Some early mobile scores, such as *Intermission 6* and *Klavierstuck XI,* solved the problem of mobility by employing a single performer and including all of the necessary information on a (sometimes very large) single page. Feldman's work comprises 15 fragments or musical objects, each a single note, chord or grace note. They fit comfortably on a standard sheet of paper and there is no great challenge to the performer in the realization of the work, namely to freely order the fragments.

Although the score for *Intermission 6* is effective and convenient in its presentation of information, a computer-based realization could offer the possibility of avoiding preparation of the event order by the performer, as well as the opportunity to choose the events using a range of aleatoric procedures and predetermine the duration and density of the work.

Stockhausen's *Klavierstück XI* provides somewhat greater challenges for the performer. The work comprises 19 musical passages or "groups", each followed by a three indications detailing the tempo, dynamic and articulation that must be applied the group that is performed next:

> *At the end of the first group, the performer reads the tempo, dynamic and attacks indications that follow, and looks at random to any other group, which he then plays in accordance with the latter indications* [32].

Each group is a complex micro-composition representing *'a sound in which certain partials, components, are behaving statistically…the wave structure of this sound is aleatoric... naturally the individual components of this piece could also be exchanged, permutated, without changing its basic quality'* [33]. The implication of this formal arrangement, where both the order of groups and manner of performing them are variable, is a potentially momentous number of realizations of the score. (Read and Yen have calculated the number as greater than 10^{40} possible permutations [34]). As a result rather than "looking at random" in order to determine the succession of events, many pianists "pre-order" the score into a particular fixed sequence.

Figure 3: The score-player for Karlheinz Stockhausen *Klavierstuck XI* (1956)

The proposed "score-player" for *Klavierstück XI* provides the performer with the musical group to play as well as the group that will follow it. The performance indications located at the end of each group are repeated above the group they refer to in the position they would normally occupy in a traditional score. The performer may choose to play the work without any precise tempo cues from the computer or receive a click and/or visual flash to negotiate the work's six tempo strata. A "Formal Variables" window allows the performer to control the relative performance duration, inter-group pause duration and whether the choice of groups should favour fast or slow tempi. The window also tracks the order of chosen groups and the duration of the performance for practice purposes.

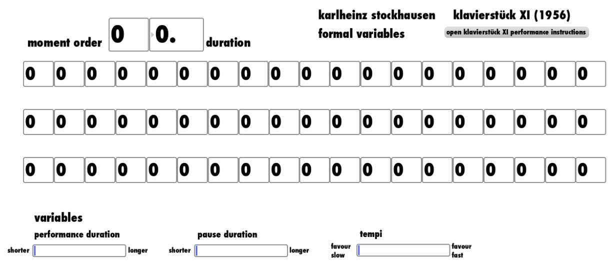

Figure 4: Formal Variables screen for Karlheinz Stockhausen *Klavierstuck XI* (1956)

Stockhausen instructs the performer to 'look at random to any other group' in order to determine which group to perform next. It is hard to imagine how the composer, listener or even performer might verify whether this instruction is being followed. In the case of a paper score however, involuntary choice is the most pragmatic solution for achieving an aleatoric order of groups. Stockhausen's stated motivation for this instruction is '*that the performer will never link up expressly chosen groups or intentionally leave out others. Each group can be joined to any of the other eighteen'* [32]. This suggests that the choice of groups through computer processes would be an equally valid method of achieving an aleatoric order and would not violate the intentions of the composer.

3.2.The multi-page mobile score

The coordination of multiple performers and scores in a live situation creates an even greater impediment to the goal of formal mobility in real-time. Preparation of the order of the events in the score prior to the performance becomes a necessity rather than just a pragmatic convenience. The following account of an early performance of Stockhausen's *Momente* (1962-69) shows the imperative for pre-ordering of the orchestral parts.

> *Stockhausen expects the performer to vary the order of movements at will, and even provides for passages from one movement to be inserted into its neighbors. For each concert the score may be re-arranged, in accordance with certain instructions; the extracts or "inserts" may be glued into certain slits in the score, and their duration and volume are varied depending on the context, as indicated by a long list of rules on each sheet. Then the parts are prepared in whatever order has been selected for the particular concert.* [35]

Clearly the pre-ordering of the performance materials prevents any formal reorganization "at will". Although the ability to assemble a unique sequence of musical events allows a form of "openness" in the score, the pre-ordering essentially reduces the work to a closed form in performance. A computer realization of this work would allow for the 99 pages of *Momente,* including its "inserts", to be ordered in real-time by the computer. The work also uses proportional rhythmic notation dividing the bars into "beat-lines" that may be a constant tempo, if regularly spaced, or a variable tempo if irregularly spaced [36]. A computer could distribute a click track to the performers alleviating the need for a conductor.

Xenakis' *Duel* employs a more radical (and awkward) means of coordination of its two orchestras. Non-notational visual cues, consisting of a complex arrangement of yellow, blue, red and violet coloured lights are used to cue the different musical materials [37]. Such a solution, in addition to being logistically complex, adds a further cognitive layer to the, already taxing, requirements for the performers and arguably creates unnecessary non-musical distraction.

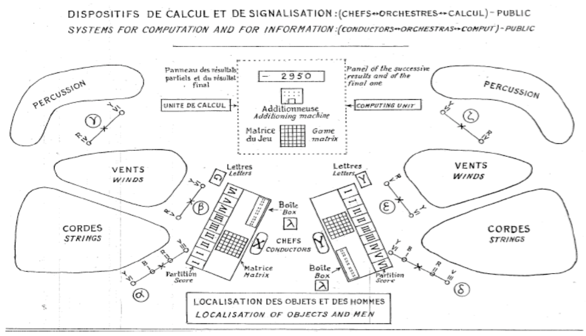

Figure 6: The arrangement of performers and visual cueing systems in Xenakis' *Duel*

Xenakis also details a system whereby '*the conductors of each orchestra duel each other, trying to score the most points over a set number of turns or time*' [38], the choices of the conductors are accorded points and continuously totaled during the performance to decide and ultimate "winner". Xenakis writes:

> *at the end of the combat one might a. proclaim a victor, or b. award a prize, bouquet of flowers, cup, or medal, whatever the concert impresario might care to donate* [39].

Xenakis also suggests that:

> *the successive partial scores can be announced automatically on lighted panels in the hall, the way the score is displayed at football games* [40].

Xenakis's requirements particularly lend themselves to adaption. Indeed, an implementation based on Xenakis' score has been completed by Liuni and Morelli [41], albeit in the form of an installation exchanging the live orchestral performers for pre-recorded sound samples.

The development of John Zorn's game pieces, numbering 27 between 1974 and 1992 [42], is shrouded in mystery due the composer's '*reluctance to publish a complete and detailed account of the work'* [43]. Zorn describes the earliest game compositions as '*creating very simple structures—combinations, for example, of all the possible duets in a twelve-piece group, all the possible trios'* [44].

The most complex (and well known) of the game pieces, *Cobra* (1984), consists of a labyrinth of cues or formal "agents", (Duos, Trades, volume change and so on), communicated by hand signals. Crucially, although there is a centralized "prompter" communicating the formal cues, the musicians themselves propose which cue should occur next. The result of this arrangement is that performances of *Cobra* have a strong theatrical element: '*what you get on the stage, is not just someone reading music but a drama'* [45].

Cobra is arguably an example of a work that would not benefit from translation into a computer-driven paradigm. What might be viewed as short-comings in Zorn's model, distracting hand-signals for example, are actually integral to the work and contribute not only to the spectacle, but to its essence as a piece of competitive improvisatory theatre.

3.3. The Mobile Graphical Score

Earle Brown is credited with composing the first instance of open form, '*filled with nontraditional notational signs and symbols, ... with the resulting shape totally unfixed and different each time'* [46]. The score for his *December 1952* is "open" in a number of ways:

> *The 'ambiguity' of the notation exists with regard to the macroform (ordering of modules or units); to the microform (how to interpret one graphic symbol in relation to its neighbours); or to the time process (between groups of materials in minute, flexible detail, as in proportional notation).* [47]

The score called for a new kind of paradigm in the performance of New Music: improvisational composition. Brown's original intention was that the performers should be left entirely to their own devices in the realization of the work, however as he later indicated, the creation of a new paradigm combining composition and performance required a level of creativity not always reached in by performers accustomed to traditional notated music.

> *I had this idealistic, romantic feeling that I could* (create improvisational composition)*, with a graphic score and classical musicians … I couldn't understand why classical musicians couldn't improvise, and why so many looked down on improvisation.* [46]

If the problem with scores such as *Klavierstück XI is* that the detailed notation lends itself to pre-ordering by performers into a linear form indistinguishable from a "closed" work, the problem with the very openness of *December 1952* is that it lends itself to improvisation with little regard for the score. The freedom created by allowing the unspecified interpretation of the range, duration and nature of the sound events as well as the orientation of the score and rate at which it should be read, leaves the performer with little necessity for precision in their interpretation.
The proposed score-reader for *December 1952* (and by extension any graphical score), features a left-right scrolling score with "playhead" representing the current moment. This arrangement allows the score to be presented in any orientation, in any magnification and to be scrolled at any rate. An optional "scalable" grid adjacent to the playhead allows the performer to assign pitch to vertical strata of the score.

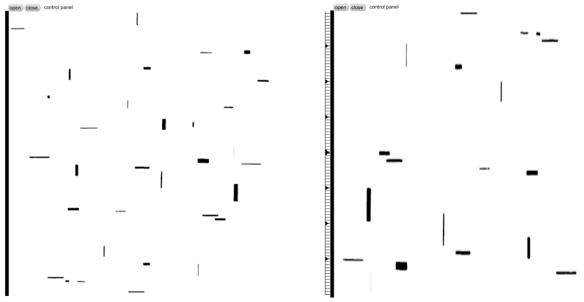

Figure 7: Two screen-shots of the score-player for Earle Brown December 1952. The second screen is the vertically enlarged, inverted, retrograde of the first.

Mauricio Kagel's *Prima Vista* (1962-3) provides for a comparable level of openness to *December 1952.* The work consists of 25 pages containing graphical notation that specifies the dynamic envelope, number and relative duration of sound events. The length of time taken to play each page is not specified.

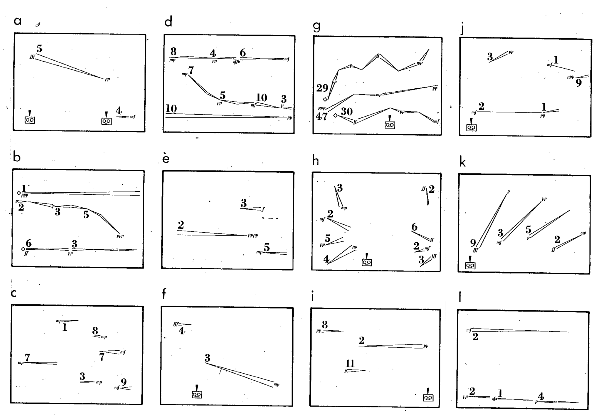

Figure 8: Score components (Letters a. through l.) of Mauricio Kagel: *Prima Vista*

Like *Duel, Prima Vista* is performed by two ensembles, but with each ensemble including a performer replaying pre-recorded samples of the opposing group. The original instructions specify projection of the score using slide projectors, a requirement that must surely have distracted aurally from the performance.
The score-player for *Prima Vista* chooses the 25 slides without repetitions and provides the performers with a countdown indicating a varying duration for each page. The available range of durations of the pages is adjustable, allowing the total length of the work to be controlled.

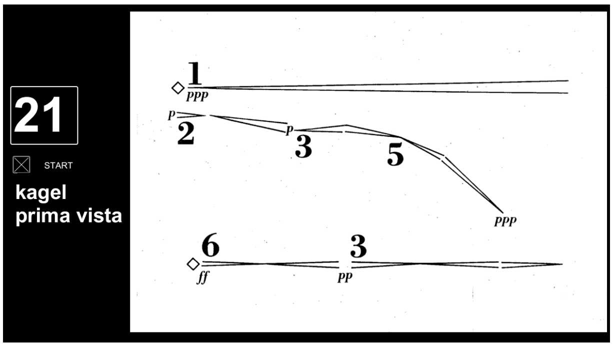

Figure 9: Score-player for Mauricio Kagel: *Prima Vista* (1962-3)

3.4.The Polytempo score

Charles Ives' experiments with polytempo techniques may date back to 1898. Three early works by Ives from the first decade of the 20th century, *Three Harvest Home Chorales* (1898-1912), *Central Park in the Dark (*1906) and *The Unanswered Question* (1908) all feature independent tempi, including accelerandi in different parts of the orchestra [48]. In the notes to *Central Park in the Dark* Ives states '*the relation of the string orchestra's measures to those of the other instruments need not and cannot be written down exactly, as the gradual accelerando of all but the strings cannot be played in precisely the same tempi each time'* [48].
The desire to obtain precise coordination of live performers led to the development of mechanical means for the management of multiple tempi by Emmanuel Ghent [49]. In his 1967 article *Programmed Signals to Performers: A New. Compositional Resource,* Ghent outlines a method by which '*performers could maintain complete independence as to tempo, meter, and positioning of the beat, and yet be precisely coordinated in time*'. The analog system used '*a magnetic tape recording on which signals to the individual performers (had) been pre-recorded at different pitch levels*' [50]. Ghent also identified the potential application of this system 'as a means of synchonising electronic tape music with live performers' and for works exploring '*wide spatial separation*' [51]. A further development of the system by Robert Moog allowed for the '*control of electronic devices such as oscillators, amplifiers, frequency modulators…*'[51].
Ghent observes that '*performers adapt very quickly to the use of the miniature headphone'* [52]. It is possible that once familiar, the regular click replaces the need for an internally generated sense of pulse and may even reduce the cognitive load on the performer.
The computer-generated clicktrack creates the opportunity not only to independently control the tempi of multiple performers, but also to transmit formal (for example nonlinear selection of score materials) and performance (such as articulation, dynamics and so forth) parameters in real-time. Such an arrangement resembles the innovative methodology of Mexican Soap opera producer Televisa, albeit with a different motivation.

> *in 1951 a Mexican engineer invented an electronic earpiece for instant communication with actors that became a standard and somewhat unique element of the Televisa production process. Performers could be fed their lines, either between takes or while taping was in process; as a result, the speed of recording was greatly enhanced* [53].

3.5. Inclusion of pre-recorded sound and/or live electronics

The final category of work places the fixed notated score in opposition to the real-time playback of a sound-file. Leah Barclay conducted a survey of performers in 2009 and concluded that in regard to performing with pre-recorded sound that:

> *the majority of artists … simply require more information and a visual representation of the electronic part* [54].

As Barclay observes the notation of the electronic component of such performances needs to be extremely accurate to match the precision offered by traditional notation and its performance conventions. An additional solution to the issue of coordination is the introduction of an on-screen timer and/or metronome to synchronise the acoustic and electronic components.
The score-player for Denis Smalley's work *Threads* (1985) centralizes the control of playback of the audio component, synchronised with an on-screen timer and mobile realisation of Smalley's score, providing the means of precise synchronization.
It is worth noting that such an arrangement also conveniently "bundles" together all of the materials necessary for a performance of the work. This is true of all of the examples mentioned and can be seen as a potential benefit to the continued longevity of these works.

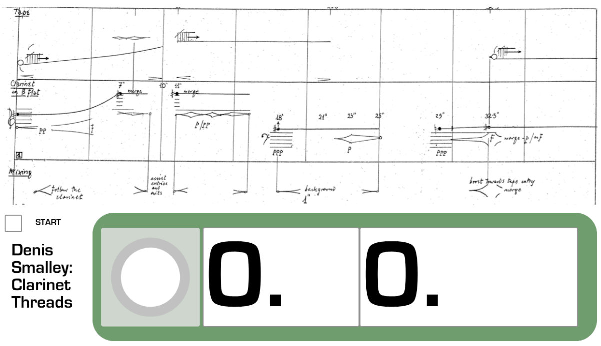

Figure 10: Score-player for Denis Smalley: *Threads* (1985)

Miller Puckette, Marc Battier, Simon Emmerson and others have written on the need to restore electronic works from the past and to preserve them into the future [55, 56, 57]. There is something of an "authentic instruments" debate on the question of the restoration of works from the past. Stockhausen took the conservative view:

> *It's extremely important to comprehend works, which were born to a particular historical moment, for their uniqueness… it is my experience of music that every instrument, every item of equipment, every technique can produce something unique, which can be achieved in no other way. Since that is the case, then we can speak of an original technique, and thus deal with an original instrument* [58].

Simon Emmerson takes a more pragmatic view.

> *But are we aiming at 'authenticity'? Once we embark on such an enterprise, the regress is infinite. Must we demand original instruments and original performance practice on these instruments? The composer's original intentions may not be inscribed in any single document, in any medium. The same arguments apply here as in the endless debates on 'early music interpretation' – except we (may) have the recorded medium to help us.* [59]

It is this author's view that technological "upgrades" to mobile form works could be considered in the following circumstances:

- the work can still be performed according to the composer's intentions
- the original work would operate more "naturally" within a contemporary medium that was not available at the time of composition.
- the "upgrade" significantly improves the performing situation, for example: facilitating more accurate performance or improving the logistical requirements for the work.

4. CONCLUSION

The potential solutions to the realisation of paper-based mobile scores proposed above can be summarized as follows:

- A dynamic mobile screen-based nonlinear or scrolling score;
- Use of visual synchronization methods such as on-screen timers or metronomes;
- Use of computer controlled click-tracks to synchronise and transmit formal or other musical parameters;
- The centralization of the score, sound-file playback, synchronization and electronic sound processing.
- The bundling of performance materials, score sound-files, electronics and means of synchronisaion into a single unit.

In addition to providing a more "natural" medium for some existing mobile scores, these solutions present a range of opportunities for the exploration of novel performance and formal paradigms.

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TOWARDS THE BETTER PERCEPTION OF SONIC DATA MAPPINGS

David Worrall

School of Music, College of Arts and Social Sciences
Australian National University
Canberra, ACT 0200

ABSTRACT

There is a well-known perceptual problem that arises when abstract multivariate datasets of a certain size and complexity are parametrically mapped into sound for music composition or data sonification purposes. In listening to the results of such mappings, when a feature appears, it can be difficult to ascertain whether that feature is actually a feature of the dataset or a just a resultant of the interaction between psychoacoustically co-dependent parametric dimensions. A similar effect occurs in visualisation, such as when parallel lines can appear more or less curved on different backgrounds. Couched in psycho-philosophical terms, we may usefully ask whether this failure is related to classical phenomenology's inability to produce an eidetic science of essential invariant forms that involve no assertion of actual material existence, or to that there not yet having been found some generalisably acceptable limits from heuristically tested mappings. This paper briefly summarises the historical, philosophical and neurological nature of this problem and outlines an empirical approach to research investigating ways to improve such mappings by incorporating a model of embodied perception.

1. INTRODUCTION

Sonification is a relatively recent and multidisciplinary research area [1]. Parameter mapping sonification (PMS) is one such technique, the most widely used for representing multi-dimensional data as sound. PMSs can have both analogical and symbolic components. Analogic variations in the sound can result when mapping from a large data domain into a small perceptual range or when data is specifically mapped to acoustic modifiers such as frequency or amplitude modulators. PMSs are sometimes referred to as sonic scatter plots [2][3], nth–order parameter mappings [4], or multivariate data mapping, in which multiple variables are mapped to a single sound[5]. In this case data dimensions are mapped symbolically to sound parameters: either to physical (e.g. frequency, amplitude), psychophysical (e.g. pitch, loudness) or perceptually coherent complexes (e.g. timbre, rhythm). The term PMS frequently refers to multivariate data mappings in which multiple variables are mapped to individual sound objects. Scaletti describes one way of implementing it by "mapping of each component of a multidimensional data point to a coefficient of a polynomial and then using that polynomial as the transfer function for a sinusoidal input" [4].

2. FOR SONICULATION OR MUSICAL EXPRESSION?

It is useful to distinguish data sonifications made for the purposes of facilitating communication or interpretation of relational information in the data, and data-driven music composition, ambient soundscapes and the like–the primary purpose of which is the expression of musical knowledge and broader cultural considerations, whatever they may be. The current use of the term "sonification" to include such cultural concerns is unfortunate because it blurs purposeful distinctions, yet today, the older expression "scientific sonification" seems unnecessarily restricted. So, for situations in which the distinction is considered important, the portmanteau term *soniculation* (from sonic + articulation) is used to mean the representation of data with sound with the principal and overriding imperative of making the structural characteristics of the data as clear and explicit to a listener as possible–even at the expense of other aesthetic considerations, if necessary[1]. In this regard, soniculation can be regarded as having a different *raison d'etre* than sonification when used as an algorithmic music composition technique, where achieving clarity for the structural characteristics of the data is not is not necessarily imperative.

Needing to maintain this distinction is not to suggest that there are not commonalities. In fact, as discussed later in this paper, the two activities can provide insights that are mutually useful. What is important is to maintain a critical awareness that because the purposes of the activities are different, so will their epistemological imperatives and consequences, such as in tool design and usability, for example.

3. "THE MAPPING PROBLEM"

There is a widely reported perceptual problem that arises when abstract multivariate datasets of a certain size and complexity are parametrically mapped into sound. Frysinger provides a useful overview of the history of the technique[6], and Flowers highlights some of its pitfalls including that while “the claim that submitting the entire contents of ‘dense and complex’ datasets to sonification will lead to the ‘emergence’ of critical relationships continues to be made, I have yet to see it ‘work’” [3]. The main limitation of PMS is co-dependence, or lack of orthogonality (linear independence) in the psychophysical parameter space. Linear changes in one domain produce non-linear auditory effects, and the range and variation of such effects can differ considerably with different parameters and synthesis techniques. These perceptual parameter interactions can produce auditory artefacts that obscure data relations and confuse the listener. A similar effect occurs in visualisation, such as when parallel lines can appear more or less curved on different backgrounds. Kramer suggests that, although a truly balanced multivariate auditory display may not be possible in practice, given powerful enough tools, it may be possible to heuristically test mappings to within acceptable limits for any given application [5].

There is general agreement among sonification researchers that “the mapping problem,” is a significant impediment to an otherwise flexible and potentially powerful means of representing such information. Yet, despite the enunciation of general heuristics, the problem has essentially remained unsolved, suggesting the need for a paradigm shift if data sonification is to realise its potential as a general means of communicating information to a wide range of people. Elsewhere, I have outlined the historical and paradigmatic nature of this problem [7] [8]. Couched in psycho-philosophical terms, it can be described as an example of the failure of classical phenomenology to produce an eidetic science of essential invariant forms that involve no assertion of actual material existence.

I also showed how this problem is related to the problem faced by artificial intelligence researchers at MIT in the 1960s and '70s who tried to build a computational model of behaviour, know as (“strong”) Artificial intelligence (AI), based on representation and predicate calculus ,and a misapplication of Shannon's information theory to *meaning*. Their atomistic approach has been all-but abandoned after its failure to represent the background knowledge and the specific forms of human “information processing” which are based on the human way of being in the world [9].

4. NEURO-PSYCHO-PHYSICAL DIMENSIONS

Neither Gestalt psychology nor neurophysics has yet found generalisably acceptable limits from heuristically tested mappings, though recent findings in neuroscience (summarised in [10]) suggest a different paradigm of perception and behaviour is emerging that involves a reconceptioning of the role of body gesture in neuronal mirroring, including in aural perception. Next, I outline these findings as they provide a conceptual basis for the approach to be taken in the research proposed.

4.1. Nonconsciousness in decision formation

Given the verifiable presence of nonconscious antecedents to an intention [11], it is unclear how formed our decisions are when we become aware and think of ourselves as ‘‘creating’’ them. The search for the neural correlates of consciousness has been aided by the ease of Functional Magnetic Resonance Imaging (fMRI) of cortical activity. However, it is suggested by Churchland and others [12][13] that the ready availability of such technologies has contributed to a cortical “chauvinism” that tends to concentrate on conscious perception at the neglect of the role they have in servicing behaviour. Specifically that, in service of keeping the body alive, the nervous systems of animals, as movers, function to service planning, deciding and executing these plans in movement.

Importantly, much of the brain’s input is consequent upon the dynamical feedback loop between observed phenomena and an organism’s own movements, exploratory and otherwise. This loop extracts vastly more information about the causal properties of the external world in a given time interval, leading to greater predictive prowess, i.e. skills regarding the causal structure of the world, than could a purely passive system.

Time is an essential component of causal knowledge, and predicting durations, interception intervals, velocities, and speeds of various body movements is critical to an animal's survival. Efference copy (being aware that a movement is one's own and not the world's) is also thought to be critical, as perhaps is the nonconscious “analysis” and memory of the movement of other movers, such as in predator–prey/pursue–evade relationships, for example. In contradistinction to the conventional wisdom that ‘‘the sensory pathways are purely sensory”, according to the Guillery and Sherman hypothesis, messages to the thalamus and cortex also carry information about ongoing instructions to the organism's motor structures [14]. Consequently, as a developing organism begins to interact with the world, sensory signals also “carry” gestural predictions: as an animal learns the consequences of a particular movement, it learns about what in the world will probably happen next, and hence what it might do after that.

4.2. Learning and memory not just cerebral

Damasio's studies of efference copying of one's own thoughts and empathy with others provide even more evidence for this thesis that perception, learning and memory are not just cerebral processes but are embodily integrated into an organism as, what Polanyi called, tacit knowledge [15][12]. Kohler et al.'s finding, not only that that certain neurons in the ventral premotor area will fire when a monkey performs a single, highly specific action with its hand: pulling, pushing, tugging, grasping, picking up and putting a peanut in the mouth etc., but that that “mirror neurons” will also fire when the monkey in question observes another monkey (or even the experimenter) performing the same action, offers some neurological basis for a theory of cultural inheritance, "mind reading" empathy, imitation learning, and even the evolution of language [16]. As Churchland observes,

> *[B]y shifting perspective from "visuocentricity" to "motor–sensory-centricity," the singular importance of temporality becomes central and takes center stage in an hypothesis that "time management," for want of a better term, is the key to the complexity of tasks of thalamic nuclei, and very probably the key to a range of conscious phenomena as well* [10].

4.3. Acoustic mirror neurons

More recent studies have demonstrated that a mirror neuron system devoted to hand, mouth and foot actions is also present in humans. Buccino, Solodkin and Small review this literature and that of the experimental evidence on the role of the mirror neuron system in action understanding, imitation learning of novel complex actions, and internal rehearsal (motor imagery) of actions [17]. Important for this proposal, is the finding that actions may also be recognised from their typical sound, when presented acoustically. Besides visual properties, it was found that about 15% of mirror neurons, called audio-visual mirror neurons, also respond to the specific sound of actions performed by other individuals even if only heard [18].

It has been argued that these neurons code the action content, which may be triggered either visually or acoustically. Phillips-Silver and Trainor demonstrated an early cross–modal interaction between body movement and auditory encoding of musical rhythm in infants [19]. They found that it is primarily the way adults move their bodies to music, not visual observation, that critically influences their perception of a rhythmic structure. Their results suggest that while the mere visual observation of a conspecific's goal-directed movement (e.g., reaching for an object or hand–to–mouth action) is sufficient to elicit a neuronal representation of the action, this does not transfer to the domain of metrical disambiguation [20]. So it appears that either this type of rhythmical body movement is not an example of the kind of object-directed action that activates the mirror neuron system or the information provided by the mirror neurons is not strong enough to influence the later-recalled auditory metrical representation of a rhythmic pattern.

4.4. Action-based sonic sensibility

In an experimental study of gestures, subjects of various ages were able, with a high degree of accuracy, on only hearing different individual human's walking and running on various kinds of surfaces, to determine their sex [21]. A consequential inference is that differences in ambulatory action, presumably resulting from relatively small differences in skeletal anatomy, is tacitly 'available' to listeners. Also consequent to these findings is the need for better models of multimodal sensory input, particularly with respect to the integrative functions of vestibulation and proprioception, which some empirical evidence suggests are available to listeners though aural means alone [22][21].

A new movement-encompassing action-based approach to the relationship between sound and sensibility began in the 1980s [23]. Methodologies include the use of abductive as well as inductive inference are contributing to new perspectives on how to approach the relationship between sensibilities [22][24]. In some ways this can be seen as a return to the Aristotelian integration of sound and sensibility through mimesis and related to the Kantian problems of openness and endness in the containment of beauty in formal structures and the empathic relationship within them through movement and action [25].

As their ability to understand musical structures shows, humans have the capacity to create, transmit, receive, transform and most importantly for the research outlined below, recall certain types of immanent objects using sound. The idea that musical involvement is based on the embodiment of movement and the bodily sensing of music, has a long history, of which the traditional connection between dance and music is but a gross example. Truslit studied the body movements of musical performers and suggested they were articulations of inner movements in the music itself [26]. Central in Truslit's approach to musical movement are the notions of dynamics (intensity) and agogics (duration). If the music has the dynamo-agogic development corresponding to a natural movement, it will evoke the impression of this movement. He makes a distinction between rhythmic movement and the inner movement of the music. In contrast to rhythmic movement, which is related to individual parts of the body, the inner movement forms the melody via the vestibular labyrinth of the inner ear and is related to the human body as a whole. Both Nettheim [27] and Clynes [28] also make a connection between music and gravitational movement, based on the idea of a dynamic rhythmic flow beyond the musical surface.

5. THE BODY IN COMPUTER MUSIC

The relationship between the rise of AI and computer music research is more than just anecdotal. Computer music developed in the second half of the twentieth century largely in its shadow, especially in the design of computer music (composition) software such as Music V [29] and its derivatives, many of which are still actively in use.

While there have been significant advances, these have been principally in the use of model-based approaches such as physical modelling for timbres synthesis and perhaps connectionist approaches more generally [30]. There is still a deep conceptual disconnection between the immediate appeal of much music made with simple electronic instruments and the commonly expressed affect that, despite the enormous investment by researchers in developing sophisticated computer sound-synthesis models in order to make them more 'life-like', much computer music still appears too abstracted and 'other-worldly' to the general public.

There are cultural and 'language' dimensions to this issue that have protected the problem from critical exposure to its causal analysis: a weakness created by a strong historical alliance between rule-based representational algorithmics and AI research [31].

This is not to suggest that no interesting music has been composed using AI-aligned techniques–music does not have to be 'natural' or even consistent to be interesting or culturally impactful, as the many of the results of using equal temperament attest– but an attempt to temper and modernise the connection between sound synthesis software and music composition in ways that take account of listeners as embodied beings. Such an approach is in confluence with the contribution that (post-)phenomenology is making to contemporary AI research [32][33].

5.1. Empirical musicology, HCI and soniculation

Merleau-Ponty divides embodiment into three modes: innate structures, basic general skills, and cultural skills [34]: the way our bodies are built, the skills we learn through our bodies, and learned ('cultural') interactions that are not directly tied to the way our bodies are built. In a growing realisation of the vital importance of accounting for the embodied nature of our interactions with the people, objects and processes, recent approaches to human-computer interaction (HCI) are attempting to make their interactions analogous to those of human-to-human and human-to-the-natural-world.

In many ways, the tradition of emphasising intentional cognition over embodied approaches has never really been totally applicable to musical sensibility. In fact, all music except those esoteric forms that seek to represent abstract algorithmic processes or in which sound is *bricolered*, encode embodied gestures in some form or another. Recent studies in empirical musicology, including the mensural study of instrumental performer's gestures, and the neurophysical analysis of instrumental performance in general, is becoming recognised as at least as important for understanding musical ideas as notated structural abstractions (scores) [35][36]. While the empirical studies of performer gestures has some relevance to the soniculation of multivariate datasets, in being more analytical than generative, it is largely deficient for the purpose.

At the same time, there is growing interest in human/machine interfaces, such as those for motion detection, that enable musicians to produce computer-generated sounds under nuanced gestural control [37][38][379. Currently, real-time performer-machine interaction is more concerned with producing convincing musical results, as traditionally evaluated, than in an empirical evaluation of the gestures themselves or their perceptibility.

However, by leveraging the analytical knowledge made available by them to the construction of generative models of information-encoded sound that is perceivable more reliably and more tacitly, that is, with a lower cognitive load, than is currently available, both empirical musicology and musical performance HCI *are* laying a foundation for their results to be applied to generating more perceptible soniculated information structures from multivariate datasets, as well as in developing new lexical tools for musical expression.

6. TOWARDS A GESTURE-ENCODED SOUND MODEL

A programme of research has begun that seeks to empirically demonstrate whether or not the perceptual access to the structural and informational content of multivariate datasets through sonification based on a model that incorporates the aural transduction of known temporal embodiment affordances such as human gestures, is superior to one based on elementally composed aural *ob*jects that are *ob*served and rationally conceptualised. Philosophically, this is an approach based on an embodied phenomenology of perception first enunciated by Merleau-Ponty [34] and extended by Todes [40].

An extensive search of the literature has not revealed any other approach that addresses the issue of how to use the innate structures of the human body, expressed through gesture and transmitted aurally, to improve the "eyes-free, hands-free" tacit grasping of ideas and information contained in the increasingly large and complex datasets that are becoming a part of our daily lives—from climate and the weather to fluctuations in the financial markets and traffic flow. The research we are currently undertaking is to develop a model of (human) physical and sonic gesture correlates. The task is essentially to apply captured biomechanical data with sound-derived components (timing, spectral morphology etc) and known psychophysical principles as inputs to an iteratively trained Dynamic Bayesian Network (DBN).

This Gesture-Encoded Sound Model will then be used to produce an active filter for transducing multivariate datasets to sound synthesis and control parameters. The approach renders a datastream to sound not only using observable quantities (inverse transforms of known psychoacoustic principles)[41], but latent variables of a DBN trained with gestures of the physical body movements of performing musicians and hypotheses concerning other observable quantities of their coincident acoustic spectra. The research on the model will be integrated as an extension to *SoniPy*], the author's open-source software framework that integrates various existing independent component modules, such as those for data acquisition, storage and analysis, cognitive and perceptual mappings as well as sound synthesis and control, by encapsulating them, or control of them, as Python modules [42].

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ARTIST TALKS

Probing Preferences between Six Designs of Interactive Sonifications for Recreational Sports, Health and Fitness

Barrass, S.[1], Schaffert, N.[2] & Barrass, T. [3]

[1] University of Canberra, Australia
[2] University of Hamburg, Germany
[3] Sweatsonics, Australia

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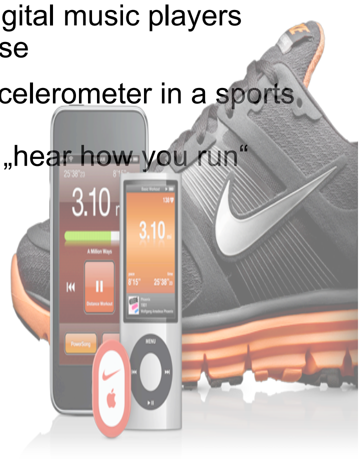
Motivation

- 1980‘s Dance Aerobics made music common in Gyms
- People now wear headphones at the gym & jogging
- Music enhances endurance & enjoyment in sports
- Small, robust digital music players allow outdoor use
- Nike+iPod – accelerometer in a sports shoe selects songs - „hear how you run“



Questions arising

- How to design **function** *and* **aesthetics** for sonifications?
- Does the usage in a sporting activity change the appreciation and enjoyment of a sonification?
- Do different sonifications induce or support different kinds of activities?

Introduction Methods Results Conclusion

Goals…

Introducing a *technology probe* methodology to investigate sonifications in real-world sporting contexts...

Cycling, Jogging, Aerobics, Kayaking, Aikido, Walking, ...

A platform for rapid iterative design, prototyping and trialling of interactive sonifications with feedback from athletes physically engaged in the sport.

Recorded data and sound files can be used in a post process as well.

Apparatus: Sweatsonic

sweatsonics – a ‘technology probe’ for interactive sonification

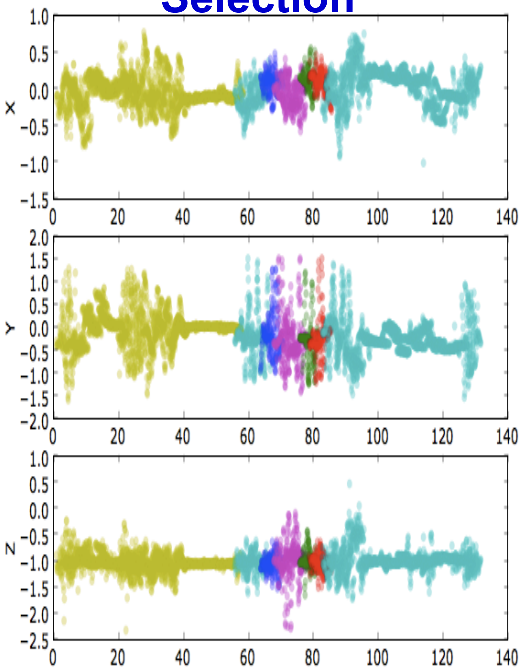
Selection sonification	
red	algorithmic music
yellow	Sinification
green	weather metaphor
cyan	formants
blue	musicification
magenta	stream-based

- Apple iPod touch with onboard 3-axis acceleration sensor (100 Hz)
  - Records timing of selections of different sonifications
  - audio output can also be recorded for later playback

Pilot study - interview and trial session

- Participants (*N*=15) = experts in Human Communication Science; males and females 20-60 years
- Pre-Interview about sonification in sport, use of music during exercises and introduction
- Probe was fitted to the upper arm and the sound information was transmitted via headphones
- Free trial-session with the probe as long as they wanted
- Post-session interview for overall impressions, preferences, and suggestions of applications and improvements

Acceleration coloured by Selection



Function and Aesthetics

Function in rowing

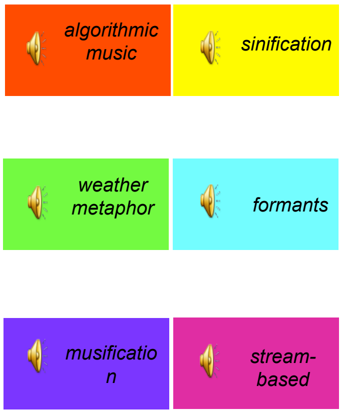
- audibly differentiated intensity steps and defined sections in the rowing cycle

Aesthetics

- Sinification : function = aesthetics
- MIDIfication : does timbre matter ?
- Soundscape and Learning
- Metaphor, Context and Sound Design
- Musical Prototype
- Stream-based sonification - psychoacoustics

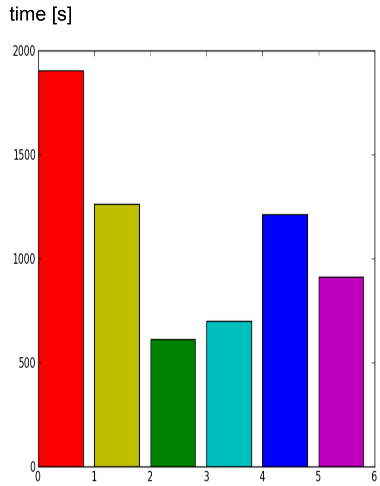
Introduction Methods Results Conclusion

Device presentation



Introduction Methods Results Conclusion

Results



- General pattern of preferences for *algorithmic* music, followed by *sinification* and *musification* across all 15 sessions
- But: different preferences among the participants: musical sounding sonification vs. informational sonic feedback

Introduction Methods Results Conclusion

Results

- Participants differed in preference:
- more conventional listening experience of a musical sounding sonification
- more distinctly informational sonic feedback (like elite rowers)
- Preferences interpreted from the data corresponded with the most preferred sonifications in the post-interview

Introduction Methods Results Conclusion

Conclusion

- The sweatsonics Technology Probe investigated preferences between six different interactive sonifications in recreational sporting activities
- The probe methodology allows experiments to be conducted in authentic outdoor physical activities rather than inside on gym equipment.
- Indications for future studies:
- Sonification with athletes in a range of sports at different levels of competitiveness and in different physical and acoustic contexts

get Sweaty too!

download the sweatsonics probe

stephenbarrass.wordpress.com

Discussion Of A Practice-Led Collaboration Between A Writer/Curator And Composer/Sound Artist

Lea Collins

ANU, Canberra, Australia
l.m.collins@anu.edu.au
leacollins@effect.net.au

Mary Hutchison

ANU, Canberra, Australia
mary.hutchison@anu.edu.au

Lea and Mary's collaboration involves the production of sound works for exhibitions using vocal and story fragments contributed by community participants. Alongside this they have an emerging theoretical collaboration which extends the dialogic form of their practice.

Mary is currently a visiting fellow at the Research School of Humanities and the Arts, Australian National University. She is a writer, museum exhibition curator and public historian. Her work has been produced and commissioned by ABC Radio and a range of Australian theatre companies. She has worked on numerous community projects and also has extensive experience in researching and developing historical and other cultural material for museum exhibitions, site specific heritage interpretations, publications and public art. Her academic background includes undergraduate qualifications in history and postgraduate qualifications in community/adult education. Her most recent research is in the field of museum studies and concerns making exhibitions of local Australian migration history in collaboration with community participants.

Lea studied electro acoustic composition with David Worrall, Tim Kreger and Warren Burt at ACAT graduating in 1997. Her artistic practice now covers the creation of site specific collaborative installation and sound work in venues such as the National Archives of Australia, the National Museum of Australia, collection of aural culture for the National Library of Australia's as well as a continuing involvement in theatre, performance and teaching. She has worked extensively in multi media, digital production and sound design providing audio, visual and technical services for venues such as Parliament House, the National Convention Centre and other corporate multi media production environments. She has developed training materials for broadcast and digital media courses at the NTU, CIT, Uni of Canberra and vocational training providers. Between 2004 and 2009 she taught at ANU with Alistair Riddell.

Collaborative projects include:

- *Migration Memories*, 2006-07, exhibitions exploring migration histories shown at the National Museum of Australia and in local venues at Lightning Ridge and Robinvale. ARC linkage grant NMA and ANU partnership.

- *Intimate Geographies*, Huw Davies Gallery, PhotoAccess, Canberra May 2005.

- *Voices of Bonegilla*, 2003, National Archives of Australia supplement to touring exhibition from Albury Regional Museum.

- Mary Hutchison and Lea Collins, 'Translations: experiments in dialogic representation of cultural diversity in three museum sound installations' in *Museum and Society*, July 2009. http://www.le.ac.uk/ms/museumsociety.html

ARTIST TALK
WIND FARM, A COMPOSITION FOR LAPTOP ORCHESTRA

John Gibson
Indiana University Jacobs School of Music
Department of Composition

ABSTRACT

The author discusses *Wind Farm*, his recent composition for a laptop orchestra of at least seven players. The piece features two sound-creation interfaces, implemented in MaxMSP, and conductor software that determines some aspects of the sound made by individual players. The conductor and players communicate over a wireless network. The gestural control interface is simple, requiring only the built-in trackpad and computer keyboard. A Jitter patch provides video accompaniment.

1. INTRODUCTION

Wind Farm, a composition for laptop orchestra, was written at the request of the Electric Monster Ensemble at Montana State University, under the direction of Hsiao-Lan Wang. The piece touches metaphorically on the promise and problems of wind energy. Wind turbines are an important source of renewable energy, but the turbines kill birds, disrupt habitats, confuse airplane and weather radar, and spoil natural views. The members of the ensemble are drawn together in a common musical effort that represents the hope that at least some of these problems will be solved.

The *Wind Farm* software comprises three performance interfaces, implemented in MaxMSP: a filtered noise instrument (*blow*), suggestive of the wind; a resonant click instrument (*spin*), reminiscent of the sound of pinwheels or spinning wheels; and a conductor patch, which plays a drone during the run-up to the high point of the piece, but otherwise sends messages to the other players over an ad-hoc wireless network.

The music is a structured improvisation. The conductor navigates a set of textural cues and pitch collections to guide the players, who focus on gestures and timbral shaping.

2. IMPLEMENTATION

2.1. Low-key Conducting

Many laptop orchestras, such as the pioneering Princeton Laptop Orchestra (PLOrk), often employ a human conductor to lead the ensemble [1]. Although these conductors have developed new ways of communicating with players (for example, via hand signals), they retain a strong sense of hierarchical organization, so familiar from traditional Western orchestral practice, that might not be desirable for this new kind of music-making.

The conductor of *Wind Farm* maintains a much lower profile, both literally and figuratively. The *conductor* patch establishes a TCP/IP network connection with each of the players in the ensemble. Then she walks through a cue list. A *cue* here serves two functions: it displays a message for the player that briefly describes the texture and density to achieve, and it triggers instantaneous and gradual parameter changes. The conductor also moves through a set of pitch collections—one for each group of players, *blow* and *spin*. The pitches are distributed to the players in a way that scales transparently to the number of available musicians. The timing of cue and pitch changes is completely under the control of the person conducting, and so her job is to listen carefully to the players' improvised gestures and determine the best times to request changes. All of this guidance happens in a visually inconspicuous manner.

2.2. Spinning

The two sound-producing patches, *spin* and *blow*, let the players control their sound within the pitch and parameter constraints provided by the conductor. In both cases, the musician uses the built-in trackpad and keyboard of the laptop to shape the sound.

The *spin* patch implements *inertial scrolling*, familiar from the iPhone and similar devices, to allow the musician to generate a decelerating series of clicks. While your finger is on the trackpad, you can create individual clicks and short, fast streams of clicks. If your finger leaves the trackpad with enough momentum, the clicks continue a while before slowing to a stop. The inertial scrolling is implemented by feeding cursor position deltas from the Max *hi* (human interface device) object to a Javascript port of the FlickDynamics Objective C code, graciously offered under the BSD license by Dave Peck [2]. (Unfortunately, this seems to work only on Mac OS X; the built-in trackpads on Windows laptops this author has tried are not visible to the *hi* object.)

The clicks so generated run through several processing modules before leaving the patch: a delay-based resonator, a resonant low-pass filter, and a recirculating spectral delay. The beginning and ending of the piece present a monochromatic sound world, with only a weak sense of pitch, in contrast to the more colourful, strongly pitched sense of the rest of the music. The pitches are imposed by the resonator, while low-pass filter cutoff frequency sweeps, controlled by a simple computer keyboard scheme, impart dramatic timbral contrasts between the sounds of the individual *spin* players. The spectral delay relies on the author's *jg.spectdelay~* external object, with source code available under the General Public License (GPL) [3].

2.3. Blowing

The *blow* patch lets the musician create a variety of filtered noise and other sounds by dragging a finger across the built-in trackpad, but without the inertial scrolling implemented in the *spin* patch. Although the trackpad is only a two-dimensional device (assuming no multi-touch capabilities), the *blow* patch divides an on-screen target rectangle into several regions that enable multi-dimensional control (see Figure 1). For example, dragging to the left of centre produces filtered noise with a relatively narrow bandwidth, while dragging to the right triggers a sustained, clear pitch, generated by the author's port of the BlowBottle physical modelling instrument from the Synthesis Toolkit (STK), by Perry Cook and Gary Scavone [4]. Near the climactic part of the piece, a sparse granular synthesis texture joins these other sounds, controlled by passing your finger through other regions of the target rectangle.

The player also operates a simple tremolo processor using the computer keyboard, while she controls overall volume with the Y axis of the trackpad.

3. PERFORMANCE CONSIDERATIONS

3.1. Spatialization

The *blow* and *spin* patches generate monophonic audio output, intended for reproduction by hemispherical loudspeakers. This type of loudspeaker is well suited to laptop ensemble performance, because it disperses sound in a much wider pattern than does a conventional loudspeaker, leading to a more natural, less focused sound, and making it easier for ensemble members to hear each other without using separate monitor speakers [5]. Placing the hemisphere as close as possible to the performer makes it more clear to the audience who is producing what sound, a consideration especially important for a medium in which there can be no fixed expectation of the kind of sound produced by a given musician. Placing players and speakers around the stage area with a reasonable amount of separation yields a vibrant, open sound with a great deal of spatial interest.

One drawback of the typical hemispherical loudspeaker is its lack of bass response. The *blow* and *spin* patches were designed to produce sound well above 100 Hz. Although the conductor plays only a single drone sound during one part of the piece, she has the distinction of generating both full-range audio, including a very deep bass that the other musicians cannot produce, and stereo sound. For this reason, the conductor requires a full-range stereo sound system, preferably equipped with a subwoofer.

3.2. What to Watch

For anyone witnessing a laptop performance, it can be hard to dismiss the nagging thought that the performers are merely checking their email. They sit motionless and stare at screens, oddly detached from the lively sounds they produce. In *Wind Farm*, a *spin* performer can alleviate this feeling somewhat by exaggerating the physical production of his inertial scrolling trackpad gestures, by moving his arm more than is really necessary. If he sits with the laptop tilted so that the audience can see the trackpad, it makes it easier for an audience member to understand what is happening. But there is probably no effective way for the *blow* player to communicate his actions to the audience, so small and precise are the finger movements required.

Partly for this reason, *Wind Farm* includes a Jitter patch that allows for live processing and compositing of wind turbine video loops during the performance.

3.3. Listening

The musical structure of *Wind Farm* encourages the players to listen to each other. In the quieter moments of the piece, when one person spins, the others should leave enough room for the gesture to speak. When a *blow* player sweeps the filter in a particular way, the others can complement this move. Because a player is not in control of her pitches, at any time she might receive notification that a new pitch has arrived from the conductor. Then she should complete her current gesture before starting another with the new pitch, all the while listening for the right moment to make the change.

It is satisfying that basic musical instincts and values can find expression in a performance context as technologically mediated as the laptop orchestra.

3.4. Performance Materials

Patches and performance information for *Wind Farm* are available at http://john-gibson.com/pieces/windfarm.htm.

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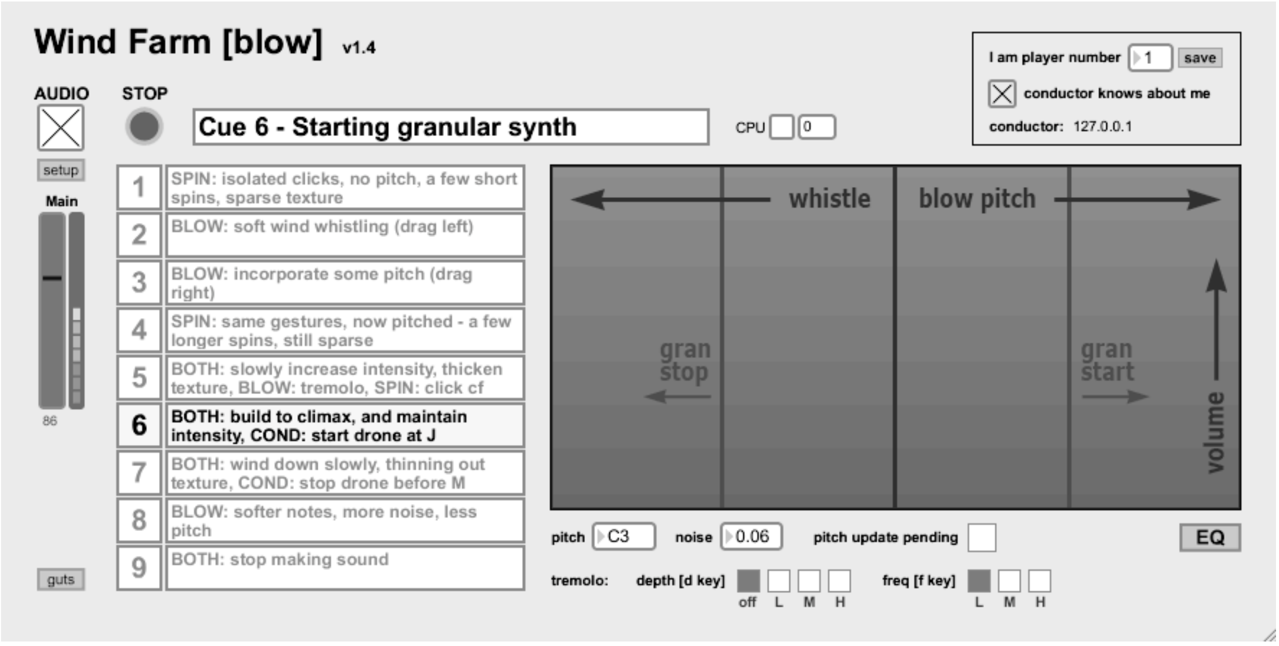

Figure 1. The *blow* patch from *Wind Farm*.

AUDIENCE INTERACTIVE PERFORMANCE IN "THE LAST MAN TO DIE"

Charles Martin
cpm@charlesmartin.com.au
Last Man to Die
Canberra, Australia

Hanna Cormick
hcormick@gmail.com
Last Man to Die
Canberra, Australia

Benjamin Forster
benjamin@emptybook.net
Last Man to Die
Canberra, Australia

ABSTRACT

The Last Man to Die is an ongoing interactive performance project by Last Man to Die, a cross artform group consisting of actor, Hanna Cormick, visual artist, Benjamin Forster and percussionist, Charles Martin. One of the goals of this project is to allow the audience to "play" with our system and enjoy unexpected and unguarded responses. This paper explains technical and artistic aspects of our open-ended performance, designed to meet this goal, and our focussed method of interaction with the audience, QR codes printed on their tickets.

1. THE PERFORMANCE

The Last Man to Die [3] is an ongoing installation and performance project involving interactions between the audience, computer driven audio and visuals, and live performers. The venue is transformed into an abandoned museum from the future that celebrates humankind's ability to extend their lifespan indefinitely. As audience members enter the venue, they are each presented with a "ticket" featuring a QR code[1] [4], scanning this ticket is the audience's method of influencing the performance.

The venue features two areas, illustrated in figure 1:

1. A theatrette area with seating surrounding a large screen and a podium with the "ticket scanning station".
2. A small performance area lit with projected visuals. A small number of audience members can view this area at a time.

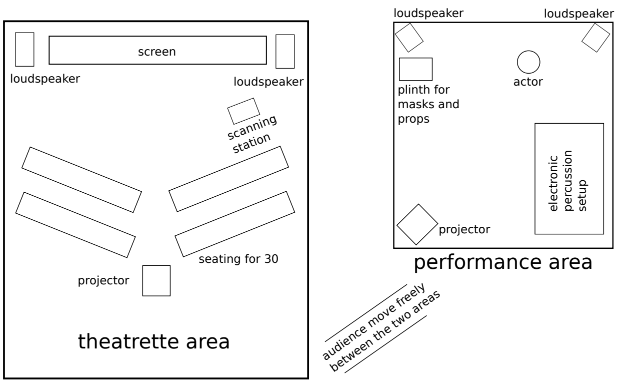

Figure 1: Stage setup for *The Last Man to Die*.

[1]QR Codes are two dimensional barcodes designed to be read by mobile phone cameras.

During the performance, audience members scan their codes to boot up "exhibits" in the performance area. The theatrette screen shows a camera's eye view of the current exhibit in the performance area mixed with recorded residue of previous performances.

While an exhibit is being performed, the audience may still scan their tickets which manipulates the visuals in the theatrette and aspects of the current events in the performance area.

The exhibits are designed to be around 3 minutes in length, with 10 exhibits performed in one showing. A typical performance session would consist of 3 showings, around 40 minutes each with 20 minutes break in between. While the performers are not present, the theatrette area continues to function as an autonomous installation. Audience members are free to arrive and leave at any time during the session.

Figure 2: The theatrette area.

2. DESIGNING AN AUDIENCE INTERACTION

The main aim of our cross artform group is to create new, implicit connections between the artforms of the three members over a performance network. Ideally, throughout our works each artist/artform both sends and receives data from each of the others. Our development process involves "playing" with these connections, searching for a balance between our individual artistic freedom and linking elements of our work together for a group effect. For *The Last Man to Die* we decided to bring the audience into our interaction, allowing them an element of control over the direction of our performance.

For Martin, a musician and Cormick, an actor, the audience is normally hidden in darkness. Forster's experience through his visual art practice is different. At an exhibition opening, for example, audience members can interact with the artist or artwork or simply observe. We prefer the exhibition style experience to interactive performance where audience members are forcibly and embarrassingly cast as characters. Rather than expect the audience to become performers, we invite them to be another data source.

With this experience in mind, we limited our design for interaction with the audience to meet the following goals. First, the interaction should be simple, audience members should understand how to interact or have it explained simply. Secondly it should be accessible, audience members shouldn't need to have particular devices or an internet connection to participate. Finally, the interaction needed to fit the context of our "ruined museum" aesthetic.

3. QR CODE TICKETS

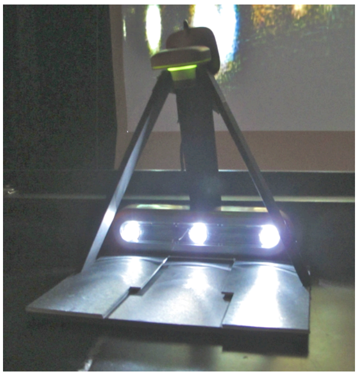

Figure 3: The QR Scanning Station

To meet our goal of allowing the audience to interact with the performers we implemented a QR code scanner using a webcam and custom software in openFrameworks [6]. QR codes were printed on tickets for the performance using a receipt printer controlled by a Teensy microcontroller [7].

This system allowed us to print codes for each audience member so that everyone was able to participate in the interaction if they wanted to. Since the tickets are disposable and easy to print, the audience could take home a unique element of the performance.

Although QR Codes are not new and are well established in advertising, they still retain a sci-fi aesthetic which suits the themes of the performance. On the other hand, many people are familiar with QR codes so little explanation of the technology was required.

In our March 2010 performances, the QR codes controlled two functions, selection of the next short scene out of nine possibilities and control over aspects of the visualisation playing in the theatrette.

Overall, audience members participated in scanning codes and did not require any specific guidance. Although scanning codes sometimes produced a strong reaction from the performers when changing a scene, the reaction was generally too subtle. Some audience members were frustrated and felt that since they didn't see an immediate result their tickets didn't work.

On the other hand, when there was a clear reaction, the audience members discussed amongst themselves what was going on, engaging and exploring our work. Inventive audience members even attempted to break our system, for example, by making new QR codes from two folded ones.

In future performances, it would be highly desirable to have more significant feedback when each ticket is scanned. Not only should we include stronger reactions in the visualisation, music and actor's actions, but a sound effect or light on the scanner would help communicate a reaction to each scanned code.

Ironically, we did not explore the usual purpose of QR codes, containing a URL. Perhaps each ticket could contain a URL leading to an online aspect of the performance, accessible through a computer or mobile phone.

4. PERFORMER INTERACTIONS

In *The Last Man to Die*, we continued to develop connections between the three artists/artforms that we explored in our previous works, *Cognition* [5] and *Vital LMTD* [2]. The connections were made through a computer network using OSC messages to communicate actions or states from each artform.

The data outputs used were:

- Martin: MIDI note output from the MalletKat percussion controller.
- Forster: events in programmed visual systems, computer vision data from live and recorded video of the performance.
- Cormick: Data from three axis accelerometer attached to upper arm.

Data inputs were:

- Martin: Musical parameters, progression through sections of the soundtrack, triggered sound events.
- Forster: Visual parameters, complexity of visual elements.
- Cormick: Four vibrating motors and LEDs attached to each hand and shoulder.

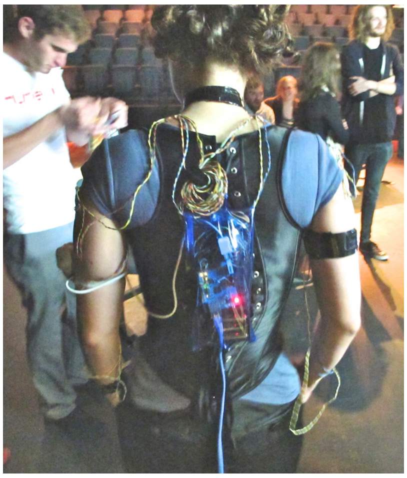

Figure 4: Hanna Cormick wearing the Arduino-based interface.

The March 2010 performance featured a wearable interface for the actor, consisting of an Arduino with Ethernet Shield [1], Nintendo Wii Nunchuck accelerometer and four paired vibration motors and LEDs. The accelerometer allowed Cormick's movement throughout the work to be connected to musical and visual parameters. We chose to limit the accelerometer data to the magnitude over the three axes. By observing this single value, we were able to program quite effective interactions. Complex impulse movements triggered flurries of panpipe like sounds and a swarm of projected jellyfish appeared to follow a current, pushed and pulled by Cormick's movement.

Cormick's outputs, four vibrating motors and bright white LEDs informed her movements and provided feedback from the musical and visual aspects of the performance. In sections of the work where Cormick was performing impulse movement, the pulses from each motor directed her gestures. The bright LEDs allowed the audience to see this connection.

In this performance, the Arduino chose a random motor and LED to pulse when it receives particular OSC messages triggered by strong actions in the music, such as a loud MalletKat note, or the visuals. In future performances each motor and LED could be connected to particular types of events in the visuals and music. Although this connection could be very interesting, the simple random choice made for a compelling performance. Sparse visuals and music led to sparse movement. As density of events increased, Cormick's movements grew more complex until finally, the instructions were overwhelming and the connection between pulsing motors, lights and the performer was visibly broken.

5. CONCLUSIONS

A prototype performance of *The Last Man to Die* was held at Belconnen Theatre, Canberra in March 2010 and development of this work is ongoing. From the prototype performance it became clear that the audience interaction through the QR code scanner was a strong and interesting mechanic for driving performance.

An additional benefit, was that when audience members engaged with the QR scanning system, they were more interested in understanding the other connections between artforms in our work. The technical simplicity allowed this system to work reliably throughout the performances and to fit in with our existing interactions.

More work needs to be done to let the audience truly feel that they are contributing to the performance. The first improvement here could be strong musical and visual feedback each time a code is scanned. Additional interactions could change throughout the work, reflecting the changing musical, visual and dramatic focus in each section.

The wearable Arduino-based interface brought compelling and reliable connections between the actor and the other elements of the performance. For future performances, we hope to refine this device to improve its appearance and shorten the setup time. We also hope to use the existing accelerometer, motor and LEDs in new interactions with the other performers and audience.

6. ACKNOWLEDGEMENTS

Last Man to Die are supported by the A.C.T. Government through ArtsACT, the Australian Government through the Department of Innovation, Industry, Science and Research and PACT Centre for Emerging Artists.

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A CANCELLED GLOW: AN INTERPRETIVE GUIDE

Stephen Stanfield
Doctor of Musical Arts candidate
Queensland Conservatorium Griffith University

ABSTRACT

This paper outlines the development of an analytical framework and interpretative guide as part of the author's Doctor of Musical Studies at Queensland Conservatorium Griffith University in the area of electronic surround-sound composition. The research focus is autoethnographical and the submission will comprise a folio of original multichannel electronic compositions presented as a surround-sound DVD, with an accompanying html document of analytical commentaries/interpretative guides. This presentation will include the playback of an original surround-sound composition as a demonstration of the developed analytical framework/interpretative guide.

1. INTRODUCTION

Traditionally the approach when writing about music composition, regardless of genre, is most often from an analytical and technical view-point, not the listening experience or related appreciation issues [3]. This common approach considers the elements of music as the primary importance for listeners to grasp an understanding and appreciation of the composition. These elements of music usually include aspects of: *pitch* (vertical/harmonic, horizontal/melodic); *duration* (rhythm, metre, tempo); *dynamic* (volume, intensity); *timbre* (instrumentation); *texture* (density, orchestration) and *structure* (formal design, architecture). In particular regards to electro-acoustic[1] works an addition to this list is that of *spatiality* or as proposed by Varèse [9] "*...sound projection - that feeling that sound is leaving us with no hope of being reflected back, a feeling akin to that aroused by beams of light sent forth by a powerful searchlight - for the ear as for the eye, that sense of projection, of a journey into space"* .

My initial analytical design followed this traditional approach and was structured within three areas I devised that related to some early creative practice musings:

i. *Temporal Space*: the structural design, linear organisation, and motion of musical events (gestures) through time
ii. *Registral Space*: the registral placement of sonic material, the intervallic distance between pitched material (harmonic structures), and the textural arrangement (density) of timbres and musical gesture
iii. *Locational Space*: the spatial placement and projection (including distance and perspective) of musical events within the stereo or surround sound performance/listening environment

However, over time questions regarding listener accessibility and comprehension emerged which have since challenged my initial analytical design and approach.

2. THE COMPOSER'S INTENTION

The impetus for this questioning has been influenced by Leigh Landy's 'Intention/Reception' project which concerns an investigation into the relationship between composer intention and listener response of electro-acoustic compositions [5]. At the heart of this project is Landy's own questioning about accessibility and his concept called the "something to hold on to" factor in timbral composition. Meaning, that many sound-based works possessed characteristics that could provide listeners with a listening strategy allowing them to understand and ultimately appreciate these works [3]. This, for myself and many other composers, is an obvious approach to the construction and design of a piece of music, but what Landy is rightly identifying is the lack of information listeners receive about a piece of abstract music in program notes and liner sleeves that would enhance their listening experience. In most cases these writings focus on the construction and technical aspects of the work as opposed to the articulation of musical content and structuring devices that can be shared with or discovered by the listener [3].

In 1994 Landy established the following categories for electro-acoustic works in which the timbral dimension outweighed that of melody or other traditional musical aspects for the "something to hold on to" project [3]:

i. Some parameters for a start: dynamics, space, pitch, and/or rhythm
ii. homogeneity of sounds and the search for new sounds, e.g. pieces based on one or a few pitches, homogeneous textures, new sounds, and the voice and the special case of a live instrument plus recorded sound
iii. textures not exceeding four sound types at once
iv. Programs, some are real but many are imaginary, e.g. nature, recycled music and "anecdotal music," and acousmatic tales
v. others not yet discovered

A second concept of Landy's in relation to the access and appreciation of electro-acoustic art music is that of *dramaturgy.* This is a term borrowed from the theatre arts and is more involved with the question of 'why' something takes place and in what contexts, rather

1 As defined by Simon Emmerson and Dennis Smalley [1]: "Music in which electronic technology, now primarily computer-based, is used to access, generate, explore and configure sound materials, and in which loudspeakers are the prime medium of transmission".

than, but not exclusively to, the 'what' or 'how' of the composition [3]. *Dramaturgy,* therefore may "contain a composer's ideas, motivations, inspirations and aspirations as well as the development of these during the composition of the work" [5]

Rob Weale's 2005 "Intention/Reception" project further explored and expanded upon Landy's original categories to include detailed elements and extrinsic information [5]:

A) Real-world sounds: (i) Source/cause, (ii) Voice, (iii) Location
B) Parameters of sound: (i) Timbral quality, (ii) Spatiality, (iii) Dynamics, (iv) Movement, (v) Morphology, (vi) Pitch, (vii) Rhythm
C) Structure: (i) Narrative (real world), (ii) Narrative (acoustic), (iii) Layers of sound, (iv) Juxtaposition of sound (real-world), (v) Juxtaposition of sound (acoustic)
D) Transformation: (i) Static transformation, (ii) Dynamic transformation
E) Homogeneity of sounds: (i) Real-world sounds, (ii) Parameters of sounds
F) Extrinsic information: (i) Title, (ii) Dramaturgy

3. FORGING A WORKABLE FRAMEWORK

Terminology and classification play a large role in developing an analytical framework and I don't believe a standardised format has yet been developed that caters for composers of differing genres[2]. My own framework certainly draws on the ideas of others and how best those ideas can be adapted for my own music. The following comprises a combination of my earlier analytical thinking, Weale's I/R project categories and specific concepts borrowed from Denis Smalley's influential 1997 article *Spectromorphology: Explaining Sound-shapes.* This is the outcome:

A) *Extrinsic Information:*
  (i) Title
  (ii) Dramaturgy[3]
B) *Sonic Elements:*
  (i) Timbre – sound sources / material
  (ii) Pitch – horizontal and vertical
  (iii) Rhythm and duration
  (iv) Dynamics
  (v) Morphology
C) *Temporal Space*:
  (i) Structural design, levels and functions
  (ii) Motion and direction
  (iii) Gesture behaviour and transformation
  (iv) Texture motion
D) *Spectral Space:*
  (i) Registral framework and placement of sonic material
  (ii) Density and textural design including distance perspective
E) *Spatiality*:
  (i) Localisation and motion[4]
  (ii) Perspective – dimensions and focus
  (iii) Spatial texture

This is by no means a definitive analytical framework, but for the purposes of my autoethnographic study and an attempt to assist the listener in the 'reception of communicative intentions' [3] of my own music, I feel it is quite sufficient and covers all aspects of my current compositional thinking and creative practice.

To illustrate the application of this framework (and gain response from readers/listeners), I have provided some analytical/interpretative information in the appendix pertaining to my composition *A Cancelled Glow.* Stereo audio examples are referenced to illustrate my compositional intentions culminating in a presentation of the entire work in Quicktime surround-sound.

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2 A selection of conceptual designs, frameworks and composition guides are discussed in: Camilleri & Smalley [2], Landy [3], Smalley [4], Weale [5], Wishart [6,7].

3 To assist in formulating my own decisions regarding this aspect of the framework I have borrowed and adapted some of Weale's 'composer intentions' questions [5, Appendix].

4 A detailed explanation of motion types is presented in Trevor Wishart's *On Sonic Art* [8], pp. 191-235.

APPENDIX

A Cancelled Glow by Stephen Stanfield

for 4-channel surround

Duration: 5' 24”

A) *Extrinsic Information:*

(i) Title	• The sound sources contained in this piece were the primary inspirational aspects for the title, in particular the names of two composers who were pioneers in exploring 'new' sounds from the piano. The title, as intriguing as it is, is simply an anagram of 'John Cage and Henry Cowell'. Ironically however it does reflect the dramatic intention of the piece.	
(ii) Dramaturgy *Where did the inspiration to create this particular composition come from?* *What are my communicative intentions concerning this particular composition?* *What is the composition's narrative discourse, if any?* *What aspects or elements of the composition should the listener hold on to? (a recognisable sound/gesture, structure, narrative, etc.)*	• Initially the inspiration for the piece emerged from improvising with the sound sources that were to be employed – inside piano hits, string plucks, scrapes and prepared piano samples. As the piece evolved the narrative idea of 'oppression' came to the forefront – the feeling of an omnipresent darkness rapidly exhuming the light, seemingly unstoppable and never ending, until a point of arrival is finally reached and the tension gradually dissolves until calm is once again arrived at. The main 'normal' piano motive acts as a question, probing and interrogating, seeking an answer...finding possibilities...and then...finding none...	

B) *Sonic Elements:*

(i) Timbre - sound sources / material	• piano sample library: inside piano scrapes, plucks and hits; prepared piano – based on John Cage's *Sonatas and Interludes* preparations; 'normal' sampled piano.	Audio Ex. 1
	• glitch/noise percussive sounds	Audio Ex. 2
	• various signal processing of sampled sounds	Audio Ex. 3
(ii) Pitch – horizontal and vertical	• melodic motive & chords built on the pitch-set: D – E – Bb – Gb – C – F – Eb – Db (0,2,8,4,10,3,1,11); derivations generated by Matrix Maker ; this pitch-set operates at a micro (motivic) and macro (quasi-structural) level	Audio Ex. 4 Audio Ex. 5
	• 'accidental' harmony – result of layered melodies / lines / drones	Audio Ex. 6
(iii) Rhythm and duration	• underlying pulse throughout → pitch rhythms/durations drawn from pre-determined matrices derived from random number generation using the units of 1, 2, 3, 4, 5 (at there lowest denomination these figures represent 16^{th} notes/semiquavers)	Audio Ex. 7
	• ordered percussion patterns → variations (x 3)	Audio Ex. 8
(iv) Dynamics	• reasonably constant dynamic shape throughout • micro level shifts in dynamics	
(v) Morphology	• development/transformation of pitch-set material • application of signal processing	Audio Ex. 9

C) *Temporal Space*:		
	(i) Structural design, levels and functions	• binary structure → approximate Golden Section proportions (0'00" - 3'32" - 5'30") • section 1 gradually increases in density and intensity as motives and gestures transform and increase in tension • section 2 commences at the conclusion of frenzied musical activity and settles into a dissolving texture of a descending melodic line, isorhythms & isomelos, a subtractive percussion sequence and register extreme sustained lines/drones
	(ii) Motion and direction	• a general propulsion to the Golden Section (3'32") and then a decrease in motion until the end (5'30") • overall there is a reciprocal motion → pitch ascension to the GS and then a descending motion to the conclusion • internally (individual background lines) there exists a prominent centric/cyclic motion
	(iii) Gesture behaviour and transformation	• 'normal' piano figure develops into rapid a ascending figure toward the end of section 1, before augmenting durationally and descending during the course of section 2 • percussion patterns gradually transform through durational subtractive and superimposed variations • bell-tone motive undergoes rhythmic augmentation in the second section
	(iv) Texture motion	• a layered textural development → an increasing density towards section 2 before a rapid textural decelerando during which the piece dissolves
D) *Spectral Space:*		
	(i) Registral framework and placement of sonic material	• quite a full registral encompassing, although upper register material can be more dominant than lower register material at times
	(ii) Density and textural design including distance perspective	• gradually increases in density (and tension) until the GS at 3'32" then begins to dissolve towards the conclusion. • much of the source material is dense within itself and contributes further to the density and tension of the whole work • variations in foreground-background perspective contribute to the textural design
E) *Spatiality*:		
	(i) Localisation and motion	• mixture of predetermined and intuitional spatial placements / movements → location of sonic materials is influenced by the character of the musical gesture and the desired perspective of the material (foreground, middle ground, background) • counterpoint of: fixed space, direct and cyclic motion
	(ii) Perspective – dimension and focus	• 'normal' piano gesture remains prominent for the most part, background material becomes prominent towards the end of section 1 and the conclusion of the piece
	(iii) Spatial texture	• reasonably complex throughout – minimal variations