Interactive control of higher order musical structures

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Abstract

This paper examines the challenge of using interactive procedures to control higher order musical structures, such as formal elements and texture. It proposes as one solution to this problem, a performance paradigm involving a cybernetic arrangement, placing a human performer and a machine in collaboration in which neither is exclusively privileged as the control source. Such a system would exploit the potentialities of the human improviser as an interactive subject in a manner practiced by some non-electronic interactive musical works and present the possibility of an open symbiotic interactive performance model in which control commands pass both *from* and *to* the human and machine components. The development of such works is explored in the context of Game Theory and non-linear compositions involving live players by Xenakis, Pousseur and Zorn as well as interactive works by Teitelbaum, The Hub, and the author's own compositions.

1 Introduction

The control and mapping of sound is an issue for a range of different interactive performance paradigms. These paradigms extend in a continuum of practices from the emulation of existing musical instruments (exemplified by the work of Kapur et al. [1], Cook et al. [2] etc) to the use of non-traditional sources of stimuli such as the movements of dancers or installation participants [3].

The control and mapping of lower order musical parameters in interactive works has received a substantial amount of attention in recent times[1]. The principal reason for this concentration may well be a very practical performative one. Designers of the systems that emulate existing musical instruments have sought to reproduce the 'one to one' relationship found in most acoustic instruments: an action results in a 'point' event. Although there has been consistent development towards a more subtle level of control *'of a note, not as a single static event, but as complex evolving sound with its own internal shape'* [10] through continuous control parameters, the underlying model is still based on the individual instrument and individual instruments are not primarily seen as being in control of higher order parameters.

In respect to interactive systems involving non-instrumental paradigms, Rovan has commented that *'an emergent integrity arises when the relationship between the dance and music systems is "believable"'* [11]. This comment is probably also true of the previous paradigm: in both cases audiences have an expectation that they will be able to "understand" the methods of interactive control. As Dobrian states:

> *Some have argued that it is less interesting to watch a performance on an interactive instrument, because the gesture-sound relationship can be so complex as to be incomprehensible, and in such a case it becomes an improvisation that is interesting only to the performer.* [10]

The most coherent mode of mapping, so called 'one-to-one' or 'direct' mapping, puts the performer in charge of what Stockhausen might term the musical 'foreground'. Such a concentration on musical foreground is reminiscent of the predicament of multiple serialism during the 1950s. The *'discrepancy between intention and result'* [12] in music of that period was noted by analyst-composers such as Ligeti [13] and Xenakis [14]. Both composers felt that the high level of foreground control in multiple serialism did not translate to higher order textural and formal parameters. Although there is arguably more to divert and distract the audience in interactive music, it faces a similar quandary: how to balance the need for recognizable 'gestural-auditory' coherence and at the same time provide 'auditory-structural' integrity and substance.

However, since higher order parameters are intrinsically more complex - being composed of groups of other parameters - the manner of their control is almost inevitably less evident than that of one-to-one interaction. It could be argued that in works in which higher order parameters are interactively controlled, questions of 'gestural coherence' are less important than the integral structural coherence of the whole performance. As in

[1] For example Lee, and Wessel, 1992 [4], Modler, and Zannos, 1997 [5], Bowler et al. 1990 [6], Rovan et al. 1997 [3], Mulder et al. 1997 [7], Wanderley et al. 1998 [8], Hunt and Kirk 1999 [9].

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notated compositions, it is not as important for the audience to see ‘under the hood’ as it is to comprehend the overarching structural or textural shape of the work. As Rovan states:

> *for some it may be enough that the system of interaction "privately" affects the performer's expression within the piece. The audience is only vicariously part of the interactive experience.* [11]

Concentrating exclusively on foreground parameters can, as is arguably the case in multiple serialism, lead to music that is too superficial to be successfully expressive in comparison with the composed score or musical improvisation. After all, listeners to piano music comprehend and enjoy it for many reasons other than a precise understanding of the workings of its mechanism.

This paper proposes an interactive performance paradigm located between the two discussed above, with control of higher order parameters as its principal concern. Such a ‘cybernetic’ arrangement would place a human performer and a machine in symbiotic relationship in the production of a musical discourse that encompasses orders of musical structure from low to high.

This arrangement would result in a system based upon interaction with the ‘performative-instrumental’ and musical-structural elements of the performance. It tackles the issue of interactivity from the composer's point of view and asks the questions: how are the elements of these higher order structural parameters understood; what methods exist to listen for them; and how might we harness these understandings in a real-time performance situation?

2 Understanding

Dannenburg has suggested that the absence of any general theory of semantics is one of the chief barriers to the codification of recognition and understanding in the field of music. He states that as a result it cannot be '*evaluated objectively in terms of how well it preserves semantic information across a change of representation*' [15].

His summary of the processes involved in musical understanding suggests that music is a predominantly self-referential language, often relying on '*repetition at different time scales*', of '*elements of the music* (that) *are repeated or transformed*'. He goes on to describe music as a form of complex domain knowledge in which '*listeners construct encodings when they listen to music, and that the encoding chosen by a listener will tend toward the shortest encoding possible*'.

The content of this encoding shorthand, according to Dannenburg is not in the form of musical elements such as melody, harmony, and rhythm, but rather '*the transfer of these elements within a composition, forming relationships and therefore structure*'. His discussion takes place in the context of cataloguing and retrieval of digital audio (in archiving for example) and centers on developing '*automated systems (that) can listen to music in audio form and determine structure by finding repeated patterns.*'

Our understanding of music is perhaps best understood from the same perspective. The field of cognitive science may provide an approach for connecting such automated systems with interactive mapping techniques by adopting a model resembling memory itself.

> *Human memory can be understood as a network of propositions and cognitive structures and can therefore be described in terms of elements or nodes and connecting relations.* [16]

The key issue in much interactive music is the ability of the performer(s) to randomly access material effectively. It is also a key issue in memory:

> *as short-term memory is limited, off-loading has to take place when we want to work on complex tasks. They see mapping techniques as a performance aid, serving as an external memory extension and as such realizing off-loading.* [16]

Mapping techniques using '*spatial, network-like visualisations for knowledge construction, organisation and presentation*'[16] might present an effective method of interfacing live performance (using analysis of digital audio such as described by Dannenberg) with the kind of complex relationships between elements found in pre-composed music.

Lazier and Cook (2003) describe a process they term '*audio mosaicing*' to both '*classify sound and to retrieve audio by content with the use of a variety of features as discriminators*'. The process '*can be used to extract global information from recordings or to compare smaller segments of sound on the local level (…) to retrieve and concatenate recorded sound*' [17]. They state that '*the ultimate goal (…) is to produce a cumulative perceptual effect desired by the artist from the combination of an ordered set of chosen segments.*' Although so far they have only used the process to '*create high quality syntheses of symbolic scores or re-syntheses of existing recordings*' [17], it represents a very potent prospect as the final phase in a cognitive based system of analysis, response and resynthesis between a live performer and computer.

Another approach might favour more rudimentary means of analysis such as the Max\MSP objects `fiddle~` [18] and `analyzer~` [19] to provide estimates of perceptual features such as pitch, loudness, brightness, noisiness, onsets, and Bark scale decomposition. All of these musical elements are useful measures of performance characteristics. Weyde has suggested that a complex system might

evolve through the categorisation and mapping[2] of the performance at this stage, particularly for elements that are 'non-hierarchical', that is unpredictable.

> *… generally any musical information is well suited for mapping that can be expressed in terms of objects (e.g. notes, chords, motifs, sections) and their relations (e.g. similarity, succession, contrast, harmonic function).* [16]

In such a system the data, which might include both statistical information about the material as well as actual samples of the material itself, would need to be managed. Dobrian outlines such a process in, stating that by:

> *Employing scheduling and storage techniques (extreme delay, capture and storage of data, reordering of events, etc.) one can shape a larger formal structure in real time.* [10]

The crucial issue here is how to design the control element, or 'rules' of such an interactive system to create an integrated and coherent structure combining the live performer and the computer. One possible direction to base such a system is the use of rule-based compositional processes such as Game Theory.

3 Models

Sward places the origin of game-based analysis in the 1920s when it '*began to be used in mathematics for predicting outcomes in economics and later human conflicts*' [20]. Its first employment for musical purposes was probably by Xenakis in works such as *Duel* (1959) and *Strategie* (1962) [12]. Xenakis '*developed a number of automated or semi-automatic compositional systems, thus foregrounding the systems themselves, derived from work in Cybernetics, including 'game' based compositional techniques*' [21]. Despite being envisioned as 'games' by the composer and including '*victory and defeat, which may be expressed by a moral or material prize, …and a penalty for the other*' [22], the 'games' in these works occur at a compositional and not at the performance level, with scores (a highly appropriate term) that are computer generated. Henri Pousseur's work *Repons* (1960) exhibits the first performative game qualities providing performers with '*a set of rules of play and … musical material which permits them to respond, with certain margins of improvisation, to all the situations into which the game puts them*' [23].

But perhaps the best known author of 'game' compositions is John Zorn who created some 27 such works between 1974 and 1992. These sets of rules, musical fragments and sometimes images, took a stance based firmly in Free Improvisation rather than notated composition and therefore radically different to Xenakis or Pousseur. The best known and most frequently performed of these works is *Cobra* (1984). Many of its rules, delivered by a 'prompt' to the performers on colour-coded filing cards, bear a resemblance to algorithmic commands. A small sample of the commands are: *Mouth 1* which directs performers to make a 'radical change' in what they are playing; *Mouth 3,* 'exchange' which directs those playing to stop and non-players to play; *Ear 3* signals a volume change; and *Head 1, 2* and *3* are 'Memory Cards' signalling that the current texture is to be remembered (it may be recalled at a later point).

For the most part the work is also devoid of explicit content[3], but is driven by a curiously 'democratic' or at least competitive form of real-time composition. To summarize, players in the group signal suggestions[4] for the next structural element (a card command) to a 'prompter' who chooses one of the suggestions and the holds up the appropriate card to enact the command. Given these conditions it is plain to see why the choice of players is so crucial. Zorn supports this perception:

> *'Each performance will be drastically different in sound and structure as the participants bring in their own private perceptions, past experiences, instrumental techniques, and interpersonal attitudes'* [24]

Importantly, the player choices are also clearly of a compositional nature, a situation that is demonstrated by the composer's actions in the case that he has not achieved a desirable line-up:

> *This even means that once he has chosen the players and the right chemistry turns out to be missing, he will not go ahead.* [24]

Franco Evangelisti founder of the improvisation ensemble *Gruppo di Improvvisazione Nuova Consonanza* signalled in 1959 that a new breed of performer would have to emerge:

> *one that was also a composer. This new figure would thus be able to link together certain musical elements which, in performances given by performers of a traditional type, are subject to the previous experience of the performer in question.* [25]

Cobussen suggests that:

> Cobra *is thus simultaneously reproducing the composer-conductor-performer hierarchy of traditional "classical" music and subverting that*

[2] This is a purely 'internal' mapping as opposed to the 'one-to-one' interactive mapping discussed earlier.

[3] The exception is the *Cartoon Trades* cards, where the performer is expected to make short cartoon soundtrack-like gesture and pass it on to someone else, but even in this case there is no attempt to specify any exact sounds or motifs.

[4] Hence the command titles such as *Ear 1* (signalled by the player touching the ear with the first finger).

hierarchy from within the "composition" itself. [24]

However, it could also be said that Zorn is simply abstracting the organizational model 'composer-conductor-performer(s)' to a point where it accepts a broader interpretation that allows for interaction between the three roles. It also broadens the notion that these functions are each prescribed to an individual, as there is a high degree of movement between three functions by *Cobra* participants.[5]

In many ways the structural organization of *Cobra* - from this high level, through the filing-card commands to the random access 'content' of individuals' improvising chops - resembles the kind of arrangement outlined in the first section of this paper for the interactive control of higher order parameters.

One of the key figures straddling the fields of improvisation and electronics is Richard Teitelbaum, whose work has centred upon the creation of 'automata': improvising electro-mechanical systems programmed by the composer to respond to his performance with a spontaneous interaction. The 'rules' here are of course based upon the composer's own experience as an improviser[6] and the impulse to create a mechanical reflection of his own playing has been likened using the popular culture icon of Dr. Frankenstein as well as the psycho-analytical example of Lacanian 'mirror-phase'.

> *In this can be seen the artists obsession with the process of creation and reproduction and humanities desire to reproduce itself, not only sexually but, if possible, through its artefacts and disciplines such as alchemy and A.I.*(Artificial Intelligence)*… The psycho-analytic aspects of this process - the artefact as a mirror of ourselves.* [21]

This comparison is of course highlighted by the performance arrangement of 'soloist and interactive electronics'. This arrangement also highlights another difficulty of interactive music: that sharing the interaction (as Zorn does between live musicians in *Cobra*) greatly reduces the degree of control for any individual performer. This is because it complicates the chain of causality in the interaction. In effect the performer is placed in the position ascribed to the audience by Dobrian in that the '*gesture-sound relationship can be so complex as to be incomprehensible*' [10].

Californian group *The Hub* sought to solve or at least embrace this problem:

> *The Hub is a computer network band. Six individual composer/performers connect separate computer-controlled music synthesizers into a network. Individual composers design pieces for the network, in most cases just specifying the nature of the data which is to be exchanged between players in the piece, but leaving implementation details to the individual players, and leaving the actual sequence of music to the emergent behavior of the network. Each player writes a computer program which make musical decisions in keeping with the character of the piece, in response to messages from the other computers in the network and control actions of the player himself.* [26]

At present interaction of this kind probably comes closest to emulating the kind of fluid command structure exhibited by Zorn's *Cobra*. *The Hub*'s composer/musicians are interacting directly with computers which not only restricts the audience's understanding of the interaction but tend to make the group resemble IBM office drones. However performances of this nature increasingly involve projection of the performer's desktops allowing a few more of the audience in on the game. But perhaps the most interesting direction is the opening up of performances for audience interaction via their own computers, thus eradicating a whole component of the 'composer-conductor-performer(s)-audience' organization.

Another potent emerging technology is that of biological art. Either through computer modeling of biological processes (generally called 'artificial life'' [27]) or interaction with actual biological material, it aims to 'breed' agents for specific purposes such as interacting with musicians or drawing portraits [28]. The 'rules' here, (strikingly similar in some respects to those of *Cobra*) can concern evolutionary imperatives such as mutation, mating, insemination and morphing [29]. In the case of Tissue Culture & Art's *Meart: The Semi Living Artist* (2001-) project, the intention is expressly stated to discover what happens 'when such a system starts to express qualities that are considered uniquely human aptitudes such as art?' [28].

Clearly akin to the 'Dr. Frankenstein' approach to creating an improvising partner, biological art presents an intriguing range of possibilities. Dahlstedt states that even in its current stage of development:

> *Interactive evolution as a compositional tool makes it possible to create surprisingly complex sounds and structures in a very quick and simple way, while keeping a feeling of control.* [29]

[5] Players, presumably when exasperated with the choices of the current 'prompt', are permitted (under certain conditions) to co-opt other performers and breakaway from the group as a 'guerrilla' group in which they themselves become a proxy 'prompt'/conductor.

[6] He is a frequent duo partner of improviser and theorist Anthony Braxton.

4 Towards a symbiotic human/machine interactive model: some examples

The following examples taken from the author's recent works to trace a trajectory towards models in which live performers might interact with technology to create what might be termed a symbiotic performance. The works show the development and exploration a range of issues related to interaction, particularly the balance of performer and machine freedom.

4.1 Performer Freedom

Like Zorn's game pieces these works spring from a desire to stimulate the spontaneous inventive qualities of Free Improvisation. The works employ a range of approaches including auditory stimulation through prerecorded or live sampling and visual stimulation through what I have termed 'Score-Films'.

Delicious Ironies (2001). *Delicious Ironies* was intended as a vehicle to provide an extremely unpredictable environment of sounds for the solo improviser. The intention was to use sound samples that were pertinent to the soloist, but also volatile and erratic enough to inspire an interesting response. For example different pieces in the series drew on morphologically related samples from film noir, boxing movies, record glitches or various extended techniques by the performers themselves.

The stream of samples that accompany the improviser in *Delicious Ironies* is controlled by nine layers of event generating objects. Each object emits the same formal structure iterated by 9 event generating objects each at different tempi. The fastest object sends cues at 9 times the speed of the slowest. Events sent from the objects are mapped to different aspects of sample playback: ie sample choice, playback speed, duration, volume, loop, pan and portamento amount.

Obviously, despite the fact that the events are 'played' by the computer in exactly the same way each time, the altered sample set generates an utterly different sounding piece each time. In addition to the aural 'surprises' in store as the computer performs the piece, the soloist may also be given a text cue to provide additional stimulation. Example 1 below shows a variety of sound suggestions (in the score they are spread out randomly over an A4 page). The performer is instructed that '*all sounds should be in transition towards something else; timbre and pitch should be in constant flux.*' [30]

Although *Delicious Ironies* was intended as an interactive work, the interaction is all in one direction. The computer's utterances act to prompt the live soloist and in the best circumstances in performance the two form an amalgam. However, despite it sometimes sounding to the contrary, the performer cannot influence the computer performance in any way.

bushmen discuss a travesty of justice in a jovial mood, washing machine malfunction, person shouting with no voice (extremely hoarse) in Italian, backwards talking little Japanese girl, distant aircraft, very very drunk karaoke singer sings birdie dance in fake German, ants communicate with antennae, weeping woman, lost homesick aliens make indiscriminate enquiries of passers-by, happy birds in birdbath, whispering sleeper, Aussie digger tells a joke, Godzilla attacking Hong Kong, Oxford don lectures on German existential philosophy, Texan gunshot victim bleeds to death, second grader recites times tables, soft shoe shuffle, late at night formula one driver relives his former glories in his head, Russian sailor tries to get his visa renewed, drycleaner explains unmovable spot, submarine pings sonar, quiz show contestant deliberates over curly question.

Figure 1. *Delicious Ironies Number 4*: vocal text cues

Splice (2002). *Splice* developed directly out of the control procedures employed in *Delicious Ironies*. It imposes the same formal structure but in contrast its contents comprise live sampling of the soloist's improvisation. It is an example of an encoded 'meta-music' - that is a compositional map that is without contents until a live performer adds them.

The soloist's samples, collected in real-time, are replayed according to the same scheduling as *Delicious Ironies* (ie playback speed, duration, volume, loop, pan etc.). In this case however the result is quite different: now the 'contents' of the computer's performance is in most respects determined by the soloist. Psychologically the process of interaction that occurs in *Delicious Ironies* is now partially reversed: the soloist is 'loading' the samples, however the computer still controls the timing of the actual sampling and playback. The computer's timing (although consistent) is opaque to the performer, creating a degree of uncertainty both about *what* has been sampled and *when* it will return. The transformation of the samples (through varied playback speed, volume and panning for example) adds a further layer of uncertainty.

The kinds of repetition and transformation exhibited by *Splice* are standard formal strategies for music. However, unlike a composer working with notated music, the computer is not discriminating in its choice of material: it sculpts any of the soloist's contributions into the same structure regardless of whether they are melodic, noise or even silence, so

though it may sound different each time it is always the same shape.

In *Splice* the process of interaction - the detail of how the scheduling is determined - is not critical to the audience. It avoids the paradox outlined by Rovan - the simultaneous desire for interconnection and freedom of both agents in an interactive relationship - because the focus of the work is not on how the soloist and the computer components are linked but the aural outcome of the two components.

The Score-Film. The exploration of projected images as a medium was also motivated by the desire to stimulate improvising performers. Another important factor was perhaps the availability of extraordinary footage of biological and endoscopical material[7] created by the *Tissue Culture & Art Group* (Oron Catts, Ionat Zurr, and Guy Ben-Ary).

Figure 2. Still frame of saxophone interior from: *Keyhole* section of *Fantastic Voyage*, © Tissue Culture & Art and HEDKIKR

In our first collaboration, *Fantastic Voyage*[8] *(2002) TC&A*'s images were edited together by the author with the express purpose of being a score to be performed live by improvisation duo HEDKIKR (Darren Moore and Lindsay Vickery) in response to the film. In performance the image and sound form a symbiotic relationship in which the complex and sometimes extreme nature of both mediums – Free Improvisation and Biological Art - is rendered more comprehensible.

Subsequent explorations of interaction contexts with film have included: *Meart/Mesound* (2002), *Microphagia* (2002) *Cytoblasty* (2002), *Pig Wings* (2003) and *Sugar* (2003). *Meart/Mesound* drawing on the installation *Meart*, is probably the most radical and most potent of these collaborations.

'MEART is an installation distributed between two (or more) locations in the world. Its 'brain' consists of cultured nerve cells that grow and live in a neuro-engineering lab, in Atlanta. Its 'body' is a robotic drawing arm that is capable of producing two-dimensional drawings. The 'brain' and the 'body' will communicate in real time with each other for the duration of the exhibition.' [28]

For some the drawings it creates have a haunting primal quality, and for others they are like a foretaste of communications with alien life. In this initial musical interaction there was no feedback to the neuron culture and our interaction took place principally with the pneumatic blasts emanating from the installation.

More recent versions of the work involve a form of interaction in which the evolving drawing is compared to a portrait photograph and the neurons are stimulated to colour the dark regions more than the light ones, in a imitation of the process of human drawing. A similar form of interaction could occur musically, but has yet to be developed.

The works *Microphagia* (2002) and *Cytoblasty* (2002) follow a different path, by making the film itself interactive. In both of these works the interaction with the film is controlled by a dancer performing in a MIBURI MIDI jumpsuit [31]. Here the musician's interaction is again with the TC&A film images, however in this case they are unpredictable and non-learnable. One aspect of the success of *Fantastic Voyage* has been the high level of synchronization achievable after repeated performances while maintaining a high degree of freedom. A future direction for this work might be the memorization of the Score-Film (to attain a high level of synchronization) and then interactive non-linear projection, to provoke novel interpretations.

4.2 Computer Control

The examples cited so far explore the use of interactive paradigms in the field of free improvisation. The examples that follow develop some of the same ideas in the context of notated music and propose some potential directions for work that fuses aspects of all of these practices.

interXection (2002). *interXection* for Drum Kit and Ring Modulator was made for Tissue Culture & Art's film Pig Wings (2003), in which they 'differentiated bone marrow stem cells to grow pig bone tissue in the

[7] The Score-film *Fantastic Voyage* features images made by *Tissue Culture & Art* of: a cell-sculpture, endoscope images of the drum-kit, the interior of the saxophone and saxophonist; a variety of assemblages of mouse cardiac cells, the ebbs and flows of a culture of fish neurons; a colour imaging a cell's structure and a close-up of veins at the back of a rat's eye.

[8] The work draws its title from the 1968 film about a secret US military organization that miniaturizes a medical team and injects it into the body of a comatose scientist from a shadowy evil foreign power.

shape of the three solutions for flight in vertebrates.[9]' [32].

The music set out to highlight the analogy of the microphone as an audio microscope by magnifying barely audible sounds from the drum kit and processing through a Ring Modulator. The intention was that the Ring Modulator would bring the source sound's component harmonics into relief in a way that is analogous to a colour imaging microscope's rendering of biological samples. However its relation to higher order musical structures lies in is its translation of the formal devices from *Delicious Ironies* and *Splice* into a notated form.

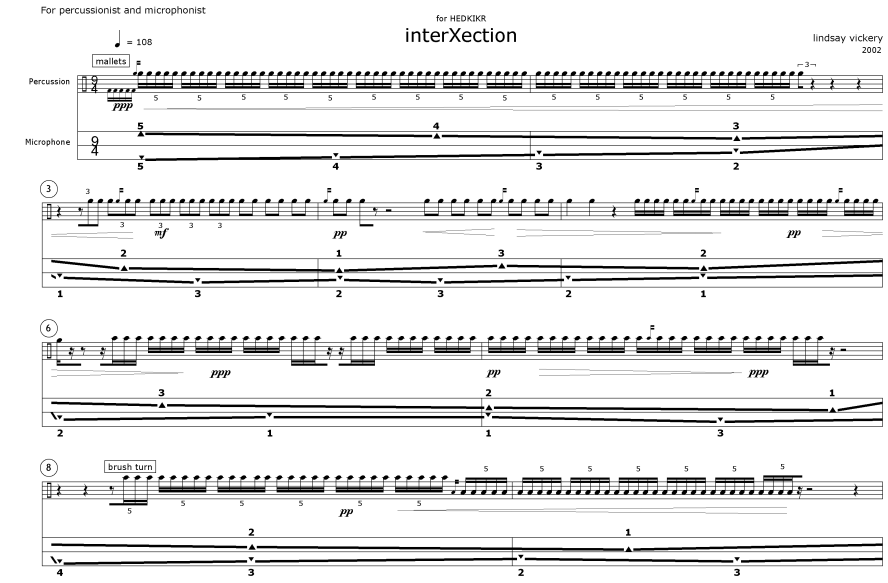

Figure 3. *interXection* score (excerpt): showing microphone position indications

In *interXection* the same structure employed by *Delicious Ironies* and *Splice* is used to determine a number of parameters including the percussionist's tempo, roll speed, instrument, mallet type, accent, dynamics, rest position and length and the vertical and horizontal coordinates of the microphonist's mic in relation to the percussionist's current instrument. This microphone part, essentially notating two 'vectors', resembles the graphic interface for automation for Pro-tools© Effects inserts. (The comparison is an appropriate one, as it is possible to imagine recreating the microphone part 'post-production'.)

It is another example of the adaptation of electro-acoustic practices such as Stockhausen's analogies of spectral analysis in *Zyklus* (1959), and *Refrain* (1959), [33]. Lachenmann's 'instrumental-musique concrete' [34] in *Pression* for a cellist (1969) or Zorn's translation of studio techniques in the cut and paste live performances of *Naked City* (1989-1992).

Whorl (2004). Tempo is one of the least explored musical parameters in live performance. In non-solo performance each additional player decreases the ability to change tempo by many times. Accurate continuous changes in tempo (ie accelerando and rallentando) are generally regarded as non-specific commands (ie we are not taught to rall. over a particular, exact duration). These understandings are embedded in our musical perception to a high degree. Even in electronic music, where tempo variations *can* be precise, they often cause a perception in the listener of separate streams of sound rather than elements of a composite texture. This mirrors the way in which timbres are unpicked perceptually by the listener and attributed to different sources.

Whorl uses the same structural framework as *interXection* to independently control three live performers via headphones. Each player receives a separately varying click-track (with five tempi and connecting accelerandi and rallentandi), as well as instructions on what dynamic, musical material and pitch set to play. This arrangement creates an unusual set of conditions for the performers in which their listening skills are divided between synchronization with the computer generated click-track and 'ensemble' playing through listening to the other players. Initially in rehearsal this results in split focus – players tend to concentrate more on one task than the other. (Arguably this split focus also occurs to a degree when normal written music is first rehearsed.) Rehearsal of *Whorl* suggests that with familiarity traditional methods of group playing begin to take effect, for example aural coordination and visual observation of bodily gestures such as are generally used to co-ordinate nuances in chamber music.

Echo Transform (2004). *Echo Transform* combines the improvisation and sampling procedures of *Splice,* and the notated score of *interXection* with a click track to create yet another performance paradigm. Although there is a score, it is in many respects more of a guide for the performers than a traditional score. For example, the first and penultimate sections notate

[9] *Tissue Culture & Art* speculate in the work: '*the rhetoric surrounding the human genome project and xenotranplantation made us wonder if pigs would fly one day and if they will what shape their wings would take.*' [32]

a single line with instructions about when players should fade-in and fade-out. The players are issued (individual) instructions to vary the line through commands to imitate, anticipate, interpolate and interrupt. Like *interXection* the score also asks the performers to 'morph' between states in a manner that is probably more akin to electro-acoustic music. For example the opening 'still' note transforms via widening vibrato to a tremelo over the first section.

As in *Splice* the sampling process is still visually 'opaque' to the performers (there is no visual sign that it is taking place and it is not notated in the score). However, due to the increased consistency of the process, (the computer will always reliably sample the same portions of the performance), the players can begin through repeated rehearsal to recognize the process aurally.

5 Conclusion

A key concern for all of the works discussed in this paper is the consideration of a wide range of musical parameters as important to the development of interactive music as an eloquent and powerful mode of musical expression. This process may involve a degree of discourse between performative aspects, such as the 'degree of believability' of the interaction, and broader concerns of the structural coherence of the music.

The examples cited indicate a direction for this research that may well involve initiatives such as: greater and more sophisticated degrees of interaction; the addition of biological agents in the system(other than humans); greater or more thorough integration of visual aspects such as interactive film; and overall, a greater level of interplay between these elements.

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