Gesture and Musical Interaction:
Interactive Engagement Through Dynamic Morphology

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ABSTRACT

New Interfaces for Musical Expression must speak to the nature of 'instrument', that is, it must always be understood that the interface binds to a complex musical phenomenon. This paper explores the nature of engagement, the point of performance that occurs when a human being engages with a computer based instrument. It asks questions about the nature of the instrument in computer music and offers some conceptual models for the mapping of gesture to sonic outcomes.

Keywords

Interaction, Music, Mind, Gesture, Mapping, Dynamic Orchestration, Dynamic Morphology, Spectral Morphology.

1. INTRODUCTION

The notion of a computer based instrument is still often establish on precepts of acoustic instruments. They exhibit, amongst other features:

- limited and usually fixed timbral characteristics, which operate on
- excitation-sonification models (attack, sustain, delay envelopes, as well as timbral structure, ie. noise in the attack stage etc) derived from existing instruments.

It is worth asking if these precepts still stand true in all cases in computer based instruments[1].

2. The Historical Imperative

2.1 Computer music

In an attempt to break the shackles of the conventional framework that defines Music, the electroacoustic composer Jan W. Morthenson suggested at the Third colloquium for the Confederation Internationale de Musique Electroacoustique in Stockholm[1] that much of the language of music should be rejected, "not only the word *music* but also *concert*, and *composer*, substituting for them *audio art*, *audio exhibition*, and *audio artist*. He proposed that "a new set of psychological and aesthetic components … be established" to offset the very strong habits created in the old musical thinking".

David Keane goes further to suggest that:

> The introduction of the computer has expanded this potential [musical potential untempered by empirical tradition], but there has been little reflection about which aspects of this potential are actually associated to musical experience. We have seen strategies used in the design of computer music facilities that owe more to past experience of musical notation or early analog hardware than to what could be identified as the relevant needs of the system or its operator. We seek to transcend the rigidly restraining shackles of traditional notation … the oscillator, the amplifier and the filter, only to build the self same limitations into systems, ostensibly because such carry-over is necessary for novices to comprehend the new systems. We hail the new resources as a release from the bondage of the limitations of acoustic instructs only to put the large part of our energies into developing programs which will approximate to acoustic instruments. We test our achievements not by seeing in which modes we can circumvent inconvenient mechanical constraints of acoustic instruments but rather by trying to convince ourselves that a computer-generated sound could pass for an acoustically generated original[2].

A recent example of research outcomes being bent to an acoustic paradigm, is contained in Tod Machover's proposal for the Brain Opera[2][3, 4] project:

> The ultimate goal of this research is to infer virtual instruments from the observation of a real instrument without any strong pre-conception about the model's architecture. Ideally, the original observation should be a simple audio recording. We also want for our inferred virtual instruments to exhibit physically realistic

[1] http://www.algonet.se/~icem/international/

[2] http://brainop.media.mit.edu/project-overview.html

behaviors. Finally, we want the nature of the virtual instrument's control to be universal and perceptually meaningful.

Machover further cements this relationship to pre-existing acoustic models within his methodology[3]:

> We first identify a set of perceptually meaningful musical gestures which can be extracted from an audio stream. *[i.e. a pre existing instrument]*. In the case of a monophonic sound, we discuss the definition and the estimation of loudness, pitch contour, noisiness and brightness *[this can only be done if the instrument exhibits a fixed timbral character]*. The second step is to investigate means by which a physically meaningful model can be inferred from observed data. … Finally, our third and last step is to suggest a strategy for applying such modeling ideas to musical audio streams parametrized by the perceptually meaningful musical gestures that we previously identified.

Of course there is much of value that resulted from Machover's research, but the sonic outcomes focus on pre-existing musical instrument models.

There have been a multitude of engineering and musical experiments, art projects and compositions in the area of interactive computer based instruments, and if we examine the sonification approaches, they are predominately based on a single synthesis instrument, be it a physical model, granular, subtractive, additive (FFT) or other existing synthesis technique. This approach accords with the acoustic instrument model, but does not acknowledge the sonic requirements of the broader musical environment [this is especially true of playable, interactive sound installations], nor does it respond to the potential for an evolution of the sonification model (and subsequent aesthetic bounds) over time.

If we go back to the basic question:

> What is the source of a sound in an interactive computer based instrument?

We have to examine the moment of performative engagement.

2.2 The Instrument

The source of a sound in an interactive computer based instrument is not some abstract or concrete concept of *instrument*, or even the algorithm(s) that have been written, but it is the gesture of the performer, the excitation moment - it is fundamentally about that nature of excitation[5] (is the excitation firm, soft, momentary, sustained, conscious, un-conscious, trained, untrained…) and not about the physical body of the instrument (for in fact, in computer music, there usually is none), nor is it therefore about the acoustic characteristics of the construction materials (wood, metal, skin, gut…), or the form of instrument construction or the way in which these construction techniques imply a relationship with the immediate acoustic environment!

[3] http://brainop.media.mit.edu/Archive/Metois/Thesis0.html

I suggest that this first moment of engagement of the performative gesture is something that we must examine in detail and come to understand better, for it is likely that there is a great deal of information in that moment that can enlighten both the interface and sonification processes.

2.3 The Embodiment of Gesture

This first moment of interaction is most probably a profoundly intuitive, corporeal one. Professor Robert Hatten suggests that:

> Musical gesture is biologically and culturally grounded in communicative human movement. Gesture draws upon the close interaction (and intermodality) of a range of human perceptual and motor systems to synthesize the energetic shaping of motion through time into significant events with unique expressive force.[4].

Hatten begins and ends by suggesting that musical gesture is biological, and as such that the human gesture central to musical production is mellifluous, viscous, and fluid, that it is not made up of individual events, but rather a contiguous movement that has form, shape, structure and duration, that "*Musical gestures are emergent gestalts that convey affective motion, emotion, and agency by fusing otherwise separate elements into continuities of shape and force"*.

These characteristics are most unusual in acoustic instruments. The Theremin comes to mind, but even the Theremin has a relatively fixed sonic aesthetic, and indeed a fixed instrument paradigm, acoustic in nature. These broader musical gestures are a product of orchestration in traditional musical composition.

Part of the question then is about the codification of gesture in musical activity to serve a specific task[6-8]. These tasks are

- formalized, and artificial,
- a construct of musical necessity, they
- vary from instrument to instrument, but,
- rarely bare the burden of acknowledgement of the 'natural' subconscious movement patterns of human activity.

Those engaged in the design of new interfaces for musical expression have to consider these characteristics. Leonard B. Meyer [9] considered the fundamental nature of conscious gesture as follows, pointing to the mind as our central concern;

> … while it is commendable for composers to be concerned with the limitations of the senses, it is well to remember that music is directed, not to the senses, but through the senses and to the mind. And it might

[4] This quote is from Professor Hatten's introductory notes to a course titled *Musical Gesture: Theory and Interpretation* at Indiana University http://www.indiana.edu/~deanfac/blfal03/mus/mus_t561_9824.html

> be well if more serious attention were paid to the capacity, behavior, and ability of the human mind.

The relationship of gesture to mind is critical in new interface design. This is perhaps the first time in history that an instrument has been designed from inception on the basis of the interface. Interaction with an instrument that uses video tracking[5] is a particular case in point, for the nature of engagement is abstract, and as such is based not so much on the physical relationship to the instrument, but the visceral, corporeal perception of the relationship of the self (physical, perceptual, psychological) to the physical space that houses the instrument or interactive installation.

The performative engagement with a gestural musical interface expands into a complex abstract one, engaging the self, the physical and psychophysical space and the sonic outcomes, where manifold decisions combine to form a realtime musical construction, a resulting perception and an audio artifact. A sophisticated closed causal loop is established, where the sonic outcomes are continually checked against the properties of the performative gesture

Keane[2] suggests a sequence in which "*the listener processes musical stimuli*", mapping the "*progression from elementary preconscious processes to sophisticated interactive operations in the conscious*": He divides them into two strata:

Preconscious processes: where

1. Most of all physical features are detected
2. some of 1 are evaluated for general classification
3. some of 2 are processed further for structural content
4. some of 3 are compared with similar features and judgments or predications are made on that basis

Conscious processes

some of 1, 2, 3 and 4 many enter to some degree into conscious consideration

The above model suggest that the embodiment of the interface, that is the immediate linking of gesture to sonic outcome[5-8, 10-23] equates to a much more intimate relationship with instrument, referred to as an *embodied* relationship *through* machines by Ihde[24]. The absence of instrument, that is a metal/wood/skin/gut construct, places the instrument, through gesture, in the mind. It is about experience and not the techniques of addressing the object, *instrument*. As Roy Ascott[25] mentions, "Mind is process not substance, or as William James[26] said, *not a thing*." Ascott clarifies the position by commenting that "*Art which is invested primarily in qualities of connectivity, transformation and emergence, while not substantial, is full of mind. It is more than the apogee of the conceptual imperative which has shaped the art of this century…*"

Whilst the consideration of art is useful in developing my proposition, it is perhaps more meaningful when considering gestural interaction to turn to a dancer, an artist who's *raison d'être* is the embodiment of experience. Thecla Schiphorst, (One of the original developers of the *Life forms* choreographic software developed in collaboration with Merce Cunningham) has written widely about the body as interface in immersive environments. In describing the human bodies role as interactive agent, Schiphorst says :

> I am interested in thinking what is body in relation to the construction of systems. I can describe the body as being fluid, re-configurable, having multiple intelligences, as being networked, distributed and emerging. … From my personal history and my own live performance experience I developed the notion of body knowledge and what I call 'first person methodology' and use this as a basis for interface design. [27]

Schiphorst paints a picture of the human body being deeply engaged on many levels with the act of interactive engagement, being intuitive, visceral, corporeal and intelligent while exhibiting parallel processing features.

2.4 Gesture review

I have spent this time teasing out ideas of 'instrument', and the nature of performative gesture, and the way we perceive or work with that gesture, because I believe it informs the development of New Interfaces for Musical Expression. It provides a basis for the consideration of the embodiment of the experience of engagement with the instrument (the performative gesture) experienced by the users of some gestural interfaces, (common also to virtual environments, especially those that use video tracking systems).

A further layer to this consideration is the breaking of the excitation-sonification binding that distinguishes acoustic instruments, one of the great promises of computer music.

If we add these two considerations together, the embodiment of the instrument, and the breaking of the excitation-sonification bindings, the notion of 'instrument' is an entirely new one, which raises some interesting questions about the nature of the new instrument, especially the necessity for a fixed aesthetic/timbral base, and the characteristics of the morphology of the sonic artifact created through gestural interaction. For instance:

1. Is it necessary in computer based instruments to have a fixed or even consistent excitation-sonification relationship?
2. If the answer to this question is no, could a new kind of instrument be perceived that changes its characteristics in relation to a changing environment or performance feature(s)?

[5] VNS, Cyclops, Eyesweb, Jitter and others

3. If so, how would one control such a change in instrument characteristics?
4. Furthermore, how would such variations evolve in such a way that the acoustic outcomes are perceivable as consistent, and make sense to the listener, or indeed the performer?
5. If computer based instruments do implement a dynamic aesthetic base, would we perceive them to be a single, dynamic instrument, or multiple distinct instruments?

I have explored these questions using as an experimental base my own interactive environments, large public art installations that take the form of gesture based musical instruments[6]. In Map1, Map2 and Gestation, I asked whether the fixed instrument paradigm is still necessary, or even appropriate in this age of powerful portable computers?

Digital technologies provide a platform for complexity. They allow us to run many envelopes, filters and other transformative processors on a single sound source, creating a rich and varied timbral structure. Additionally, software provides a relatively fast and extensive way to intervene in the data path, and reshape it in a dynamic fashion.

By contrast existing musical paradigms suggest the creation and collection of individual events that equate to single points of action and only become part of a continuum of movement when contextualised within known musical forms.

3. Dynamic Orchestration

By way of evolving some alternative approaches to electronic musical interfaces, I have developing the conceptual model of Dynamic Orchestration, drawing heavily on the concepts of Dynamic Morphology[28] and Spectral Morphology[29]. Dynamic Morphology[28] is a conceptual model developed by Wishart (based in turn on the work of Schaeffer[30]), for acousmatic composition, but which I propose can be applied to both sound generation and gestural interfaces, suggesting a continuously evolving stream of sound events (audible or silent).

Wishart defines two primary areas of morphology

1. Gesture, which is "*the articulation of the continuum by the agent which instigates the event*"
2. The classification of morphology used "*in relation to perceived natural phenomena*".[28]

The morphology is only apparent if the sound-object is perceivable as a whole. Wishart comments;

> We may expect, … that the category of gesture is in some ways more restricted than that of natural phenomena structures … It is in other respects more extensive than the category of natural phenomena - higher organisms are capable of very subtle articulations of the continuum, which we should only expect to find by chance in the structures of a natural phenomena.[28]

6 http://www.activatedspace.com.au/Installations

Human gesture is characterised by a smooth, continuously changing relationship of the limb to the body, each movement being made up of many infinitesimally small variations and adjustments. The overall movement defines a gesture, and the nature of the way in which that gesture is enacted is described as it's weight.

Computer music is also characterised by continuance of variation and adjustment. Similarly a single sound is perceived as a whole, not as a collection of the myriad samples that create it in a digital playback system, but as a stream of contiguous sonic information. Whilst it is possible with a computer to extract a single sound sample it is meaningless to the human ear. Wishart points out that:

> In general, sound objects with a dynamic morphology can only be comprehended in their totality and the qualities of the process of change will predominate in our perception over the nature of individual properties.[28]

If dynamic morphology is applied to the design of responsive and interactive instruments and installations, it becomes clear that the system design itself must be dynamic, and that during an interaction, an instrument must be able to change in fundamental ways to produce timbres that were impossible at its inception. In other words, it must be possible for it (in accordance with the nature of interaction) to evolve into a new instrument altogether

For the gesture of a performer to be fully inscribed within a realtime sound output, the sound must evolve and change in such a manner as to correlate with the qualitative development of the gesture, an evolution of momentary events, which is unknown to the system at any point prior to their execution. The morphology of a particular gesture is unknown even at the beginning of the movement; The performer may change the direction or speed of the movement at any time, and may alter the position of the limb in both the vertical and horizontal planes at a rate of change that does not match any previous event. This will occur even when the player is attempting to perform the gesture in an identical way to a previous movement event. It is only the highly trained dancer, with a spatial awareness developed over years of exacting training who can reproduce spatial positioning, rate of change and horizontal and vertical gesture within sufficient bounds for us to perceive them as repeatable. To the video analysis system, even these highly trained executions alter in subtle ways.

The evolution of the timbre space as a correlate to the qualitative development of the performative gesture is what I have termed Dynamic Orchestration. Dynamic Orchestration applies the ideas of dynamic morphology beyond the scope of varying a fixed audio stream through the use of equalization or other filtering, or an otherwise variable synthesised output from a collection of algorithms, (which no matter how the algorithm is designed will have a finite range of aesthetic and timbral variation), to a dynamically forming orchestration. In such a dynamic orchestration, a new sound object would be created when the morphological scope (by which I mean the aesthetic range of expression) of the current algorithm is reaching its limits. The new algorithm may exist only as long as it is required, and may be augmented by other dynamically created instruments, before being disposed of. Interactive input very may generate something similar at a later date, but it will exhibit variation in accordance with the varied collection of the conditions of creation.

Any synthesis approach that does not allow for the realtime addition of new algorithms is inherently limited. For instance, it is not possible to add a band to a filter in realtime, an entirely new filter object must be created and the previous object dispose of, which creates a disruption in the audio signal. Lexically separate synthesis processes are required for true dynamic morphology of synthesis processes.

Current software tools mostly assume the predominant paradigm of music composition, whereby the composer/programmer creates the resources they expect to need for the entire composition at the beginning of the work. These resources contain a set group of instruments, with are inherently limited aesthetic and morphological scope, a limitation, that I have come to believe has no place in interactive electronic music performance, because:

- it does not address the human context, by this I mean it has evolved to cater for existing musical practice and neither addresses the potential flexibility of computer music systems or the developing range of approaches to interfacing with interactive music system.
- it is not driven by artistic values, it is predicated by programming limitations,
- it is aesthetically limited,
- it does not allow for the evolution of a musical work over an extended time frame, where the context for the work may also change, and
- it caters to a paradigm based on a pre-determined musical work being performed by an expert performer, and as such, does not cater to the indeterminate form or resource requirements of an interactive musical installation being ‘performed’ by inexpert agents (the general public).

I have not yet achieved these goals in full myself, but will briefly illustrate two attempts to explore the possibilities of Dynamic Orchestration.

4. Interactive Installations

4.1 MAP2

My responsive interactive environment MAP2 explores the object oriented programming approach as a mechanism for dynamic orchestration. The music programming language SuperCollider was used to create an eight-channel instrument. MAP2 is a three dimensional space which can be entered and encountered, played and played with. It is a virtual musical instrument using the movement of those within it to compose music in realtime. There is no pre-recorded sound material in MAP2, all sound is generated in realtime in response to the speed, direction, position and quality of movement of those within the installation.

MAP2 uses video sensing (VNSII) to map the movement and behavior patterns of people, within the installation, into sound. The synthesis approach uses a number of algorithms collected into an orchestra. The instrumentation is augmented each time the sensed activity increases above a certain threshold. The horizontal space is broken into quarters, each independently sensed, allowing four ‘players’ to perform the installation (instrument) simultaneously and asynchronously. Multiple synthesis algorithms are available within each of the four horizontal zones; each zone being an independent instrument. The output of those algorithms is controlled by the position and dynamic threshold of gesture within the instruments zone. Each of the four zones has slight variations in the synthesis algorithms providing a diversity of timbre. The variation is achieved using filter bands that change their makeup based on the sensed activity.

Each zone is allocated a pair of loudspeakers. Eight loudspeakers surround the installation. The **zone >> loudspeaker** relationship means the sound follows the individual through the installation space, thereby echoing one aspect of the initiating physical gesture.

MAP2 implemented two synchronised video cameras creating a 3D sensing space, allowing height information, and vertical position to be applied to separate synthesis parameters.

4.1.1 MAP2 - Mapping

As mentioned above, two cameras were used for MAP2, each with its own mapping strategy and audio output. Both cameras used a sensing map that defined sixty-four regions in an eight column by eight row grid.

Each of the 4 horizontal zones contained three instruments (Layer01, Layer02, and Layer03) that responded to different levels of sensed activity. These instruments created a dynamic orchestration that was designed to provide a continuous and direct change in the audio timbre in relation to the dynamic of movement. Each time the movement exceeded the layer threshold, a new instrument would come into play in addition to the existing instrument. This created an overlapping of sound textures, producing a graduated change rather than the sudden change that would have resulted if the lower threshold instrument were superseded by the new one.

In addition to the dynamic orchestration approach, filter banks were placed on the output of each audio channel. The filters were designed to change their central frequency in accordance with the region indicating the most activity.

Comb delay lines were used as a resonator, the resonant fundamental being equal to the reciprocal of the delay time. The comb delay creates a varying resonant filter, driven by the sensed activity in the installation. This technique was applied in all three layers, and generated a viscous, visceral sound environment that fluidly mapped the gesture patterns in the installation.

As I mentioned earlier, the four zones were completely independent, and applied slightly different filter settings, therefore producing differing timbres. Four people could therefore play the installation simultaneously (one in each zone), or groups could play as an ensemble. [MAP2 Video]

5. GESTATION

5.1 Sound/Gesture Mapping

Like MAP2, Gestation[31] used the dynamic of movement within the installation space to control dynamic orchestration processes, and the position of each movement within a zone (4 zones) to control filter and other synthesis variables. Many of the synthesis variables operated within ranges; the ranges were altered depending on the current dynamic of activity in the installation.

The basis for each of six sound algorithms was set-up in a Kyma[7] timeline, which allowed the dynamic control of spatialisation, and the layering of the sounds. The sound algorithms are shown in the timeline in Figure 3 with the base sound in track one, and the higher order sounds in tracks two through to six.

The six algorithms developed for Gestation became active at different levels of activity within the installation. The sound aesthetics can be described as follows:

1 A watery drop like sound that created a sense of a fluid, viscous, womb like enclosure.

2 A low frequency bass drone. The position of greatest activity in the installation space caused changes in the sounds texture, while the bandwidth of the signal varied in accordance with the dynamic of activity within the installation.

3 A high frequency drone, which had a female voice like quality. This sound was generated using a vocal sample as an input to an FFT, IFFT additive synthesis process. The spectra of the FFT analysis were varied in accordance with the activity in the installations, generating changes in pitch and texture.

4 A bubbly, dynamic sound formed the fourth layer. Its pitch and dynamic of temporal structure was controlled from the installation.

5 A female breath like sound formed the fifth layer. This sound was based on a granular synthesis process, fed with a female breath sample. The density of grains, the length of the grains, and the temporal structure of the sound output was driven by the video data from the installation.

6 The final level of sound was a baby giggle. This sound was based on a spectral analysis file of a female baby's giggle. The way in which the spectra were used in the resynthesis was changed in accordance with the activity in the installation space. A set of delay lines were also placed on the output of this sound. Activity within the installation set the echo rate, delay feedback, and delay/dry signal mix, causing variations over the duration of the synthesized sound. An envelope for these delay characteristics, and the time over which the delay envelope was executed were defined in the Gestation Max patch, and varied in accordance with activity in the installation.

Scripts could be added to the sounds to change defined characteristic during run time. In addition to the dynamic orchestration approach taken in previous works, I defined differing ranges for the scaling of sensed data onto sound synthesis algorithms based on the overall dynamic of activity within the installation. This approach provided micro-scale adjustments of the timbre states within certain available activity ranges. It also meant that an algorithm could be written that had a much broader scope for variations in output; an algorithm that was much more dynamic and mercurial. Because the variables being fed to the algorithm were being scoped in the Max patch on the basis of current activity levels within the installation, a lot more variation could be achieved in the aural output from a similar number of synthesis algorithms used in the previous installation. [Gestation Video]

6. Conclusion

In summary, I have outlined above the importance of considering the nature of the performative engagement with a gesture based electronic instrument as a central tenant in the design of New Interfaces for Musical Expression. Video based interfaces afford a high degree of embodiment of the instrument, and lend themselves to being described within the context of Dynamic Morphology[28]. The application of the Dynamic Morphology model to both the sonification outcome and the gestural input has led me to the develop, Dynamic Orchestration, in the hope of truly reflecting the minute, individual nuance of the moment of performative engagement.

There is much work still to do to fully implement these ideas, but the two works illustrated above show that there is promise in continuing this approach.

[7] Kyma http://www.symbolicsound.com

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