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Implementation and Development of Interfaces for Music Performance through Analysis of Improvised Dance Movements

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ABSTRACT

Electronic music, even when designed to be interactive, can lack performance interest and is frequently musically unsophisticated. This is unfortunate because there are many aspects of electronic music that can be interesting, elegant, demonstrative and musically informative. The use of dancers to interact with prototypical interfaces comprising clusters of sensors generating music algorithmically provides a method of investigating human actions in this environment. This is achieved through collaborative work involving software and hardware designers, composers, sculptors and choreographers who examine aesthetically and practically the interstices of these disciplines. The proposed paper investigates these interstices.

1. BACKGROUND

1.1. Two Cultures

The aesthetic perspective guiding the work presented here is from the arts, although, as I hope to explain, the intimate interchange between art and technique in this work is impossible to fully unravel. C.P. Snow's *Two Cultures* [2] are in fact uniquely combined in music, where the (sometimes literal) manipulation of technology, whether computer or penny whistle, lies at the heart of most performance.

This is certainly true in the case of the work presented. None of the techniques described here are particularly original: the technologies involved have all been available for a long time. Similarly, the technologies involved in the programming of algorithmic material for SuperCollider [9], [10] are hardly original. However, the ability of a single developer to be able to undertake the whole process to completion is more novel. The ability to synthesize such complex audio in real-time has only become feasible over the last ten years, and, of course this is a prerequisite for the development of any systems involving audio processes generated through physical interaction with computers. SuperCollider itself is only fourteen years old. The current interest in 'making' is similarly a 'new' phenomenon; perhaps only recently creative artists and technicians alike have begun to realize that only working digitally with computers is not always an entirely rewarding activity. Years spent attempting to synthesize 'natural' sounds - a very valuable activity in itself - have proved to developers and manufacturers that some live input is more desirable than ever (as well a lot of fun) in music.

1.2. Inventing Expression: Physical Metaphors

The work presented here is an investigation of metaphors lying behind methods of generating expression in standard acoustic instruments and the possible development and expansion of these metaphors. Typically the acoustic musician has access to few parameters, each of which are infinitely controllable: the strings of a violin, the perforated tubing of a flute. The physical interface to an extent defines the controllability, and it can be said that the interplay between musician and instrument is a very significant aspect of musical expression itself.

Generic and performance-based systems of algorithmic management have become more commonplace as commercially available technology has developed. This is particularly the case with technology surrounding games and other consumer IT products (for instance the Nintendo Wii, the Microsoft Natal and the Apple iPad), where viscerality is increasingly seen as particularly important. These systems now commonly allow significantly more physical control of some algorithmic processes, although the latter are frequently very limited and controlled, a situation sometimes unfortunately reflected in the quality and scope of the resulting action.

A central concern is the nature of the metaphor that exists between physical action and computer reaction. Current technology allows, even with relatively low levels of expenditure and specialisation, increasingly convincing metaphorical links between user and computer. In gaming, the emphasis is inevitably on the realism of these metaphors, that is, how well they correspond to action in 'reality'. In music, excepting areas such as physical modeling where realism has to be the goal, the objective is more elusive and, possibly literally intangible in cases of interfaces like the *Gaggle* (see below) where physical contact is not relevant. If a physical action entails the stroking of some sculptural wires, what sonic/musical reaction should this produce? Should it be the same each time the action happens; should it be similar. Maybe it should be entirely different. What about levels of expectation and predictability, and how closely should function follow form? Must the metaphors for control be constantly invented, developed, rehearsed, redeveloped and how will this effect the resulting music?

1.3. Previous Research

It is beyond the scope of this paper to give a full account of the history of algorithms in music. However, comprehensive surveys of algorithmic music can be found in chapters in *Musimathics Vol 1* by Gareth Loy [15], chapters from the upcoming *SuperCollider Book* (particularly chapter 23 *Dialects, Constraints and Systems with Systems* by Rohrhuber, Hall and de Campo) [16], the comprehensive *Composing Music with Computers* [17], as well as Cope, [18, 19], which concerns more stylistic aspects of generative music.

Over the last twenty years the investigation and implementation of physical computing and embodiment has become increasingly popular across all fields. Whatever the reasons for this - the familiarity of standard computer interfaces breeding contempt (although there already seems a role for nostalgia in some places [20], the rise in interest in making, do-it-yourself (DIY) and recycling which has also led to interests in hardware hacking and circuit bending [21, 22] - the number of performances and analyses of hardware has grown dramatically recently. Amongst many significant contributions, issues of *Computer Music Journal* (14:1, 14:2, 22:1, 26:3), *Organised Sound* (7:2, 7:2), and *Contemporary Music Review*, (6:1). Miranda and Wanderley's *New digital musical instruments* [23] provides an introduction to the area of physical control of digital methods in the creation of sound and performance. Specific to physical computing is Sullivan and Igoe [24] and specific to the Arduino is Banzi [25].

Probably the artifact closest to the current version of the *Gaggle* interface described presently is the *Sound=Space* installation by Rolf Gehlhaar [14]. This variable room-sized installation is described as having a number of configurations and purposes: including use as sound-art installation, use for dance and therapeutic use. Gehlhaar describes a series of possible *topographies* for use in different environments and for different purposes, for instance 'changes in themes and rhythms' or action creating a melody. The principal disadvantage apparent in this system concerns its lack of flexibility. The installation is based around a number of units each of which used a single pair of ultrasonic sensors (to a maximum of 48 at the time of the article's writing). These are set up around a space (rather than in it) and the topography is put in place to express particular kinds of activity and in order to obtain particular results

In contrast, while the results have been as interesting and exciting as Gehlhaar's have been with *Sound=Space*, my own experience with *Gaggle* is that further developments certainly involve more work on different topographies, the principal areas of development lie in other types of interfaces made from clusters of varying sensors, materials and environments. The realization of a monolithic scene that is capable of being flexible enough to display sufficient quantity and quality of expression is, I think, optimistic. I would suggest that future expression would be small, flexible and heterogeneous.

A further area of research that has become increasingly important, as the work has progressed involves HCI and particularly the way that performance encourages or contradicts physical metaphors. This is a large field and specific discussion of its history and the use made of metaphor, design and reality is discussed fully in Blackwell, 2006 [29]

1.4. The *Gaggle* Interface

The *Gaggle* interface [1] was originally conceived as an improvisatory interface for the control of generative, automatic music. Generative aspects would control most aspects of the music including pitch, duration and timbre. This in turn was the result of a number of years working in the area of generative or algorithmic composition. The purpose of this was almost entirely in order to help me understand the creative process itself through developing software that emulated it, and a very clear part of that emulation has always been recreating, or at least taking account of those elements of 'liveness' that inevitably make live performance so satisfying. These elements, investigated in depth elsewhere [15], include aspects of indeterminacy, most obviously the repetition of melodic, rhythmic and timbral material with variation and the software encapsulation of various global structures such as the length and order of particular groups of material.

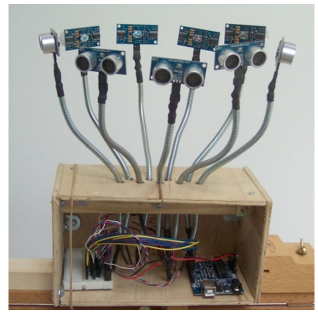

Figure 1 *Gaggle*

Gaggle was originally designed for use at the HCI 2009 conference in Cambridge UK, where my colleague Tom Hall and I were invited to contribute to the Open House Festival [26]. At this point the device was an experiment in multi-dimensional control of multiple musical parameters. It comprised nine ultrasonic sensors held in place by stay-put tubing (goose-necks). The sensors were used to 'manipulate' a musical patch written in the SuperCollider audio language.

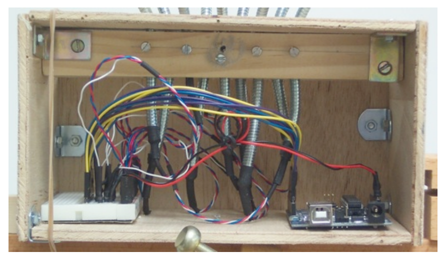

Figure 4 The *Gaggle* inside

Readings were taken from the sensors via an Arduino board [3]. A more detailed description of the whole interface system is given below. As well as the *Gaggle*, Tom Hall was demonstrating his music created using the delightful and new Manta interface from Jeff Snyder of Snyderphonics [5], and a postgraduate student, Krisztian Hofstadter, was demonstrating his novel EEG interface [28].

1.5. Movement and Dance

As an experiment, we were asked by Alan Blackwell, one of the conference's organisers if we wanted to collaborate with a choreographer, Jane Turner, and her group of dancers [6]. While concerned over the short space of time available for planning and rehearsal and with some trepidation we agreed and made some considered alterations to our plans based on the new scenario. We were also to work with Stuart Taylor and his Microsoft Surface/VJ system

[7]. As a result we only had time for a single day's rehearsal – in reality a matter of a few hours with the six dancers. In this time, the various interface components including the *Gaggle* were put in place alongside the other live performers: the six dancers under the choreography of Jane Turner and the composer and excellent pianist Cheryl Frances-Hoad [8].

The short amount of time available proved both irrelevant and a very positive factor. From the first contact between the dancers and the *Gaggle* there seemed a connection; the dancers, who had experience with the use of technology in performance, were both curious and interested in the interface and its effects. For the performances themselves, a routine involving the dancers entering the space while the *Gaggle* responded to the delegates milling around the various exhibits, including our own, a short series of interactions with the *Gaggle* before a more extended performance involving Tom Hall and the Manta and Cheryl Frances-Hoad on electric piano responding to the dancer's physical position in the space. Because of the lack of time for more formal rehearsal, I had prepared a number of performance variations any of which could be used depending on the environment, the mood, the responses of the performers and the public, but in reality very few of these were necessary.

2. THE PERFORMANCE

2.1. The *Gaggle* System

As has been mentioned above, the *Gaggle* interface as demonstrated at HCI2009 comprises nine ultrasound sensors: in this case *Ping* units manufactured by Parallax [11]. These particular units work by instructing an emitter to output a 40 kHz frequency sound for 200 µs (see Figure 3). The pulse is then read on its return and duration of echo calculated. This provides a quite precise indication of the distance of any solid object positioned directly in front of the unit to a manufacturer's limit of 3m. The intention is to custom build these units in future to continue to develop precise control and understanding of the process. The ultrasound units were held in place with 'goose-neck' stay-put tubing potentially allowing for significant freedom and customization of placement of the units. This was established initially when I was planning to demonstrate the unit using my own movements.

2.1.1. Arduino

The *Ping* units interfaced with an Arduino prototyping board. This cheap but effective and increasingly ubiquitous platform uses a straightforward and simple to learn programming language based on the *Processing* language [30]. This resulted in each sensor sending a stream of values to the SuperCollider audio language. The limitations of this particular use of the Arduino platform were here manifest as there was significant latency between the readings from each ultrasound unit. To reduce this latency a *Teabox* [4] interface has been used experimentally, the signals of which, running as they do at audio rate, provide much higher resolution.

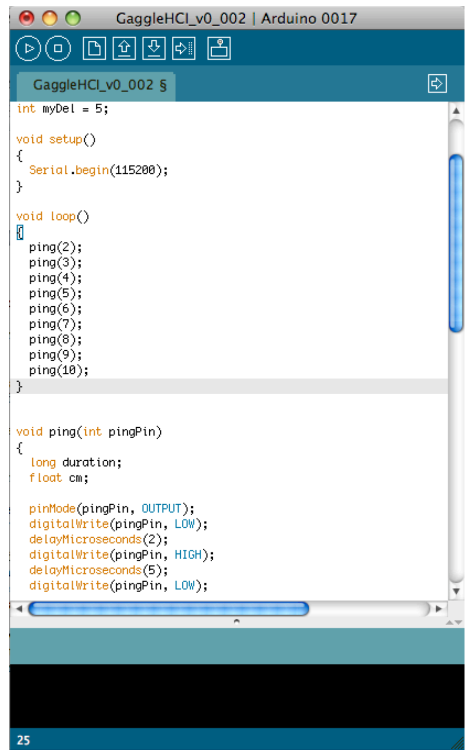

Figure 3 *The Arduino coding environment*

All other manipulation happens in the SuperCollider environment in order to minimize load on the Arduino's CPU but in any case the only other requirement as far as the hardware interface is concerned is that the readings should be calibrated in accordance with room size and performance requirements.

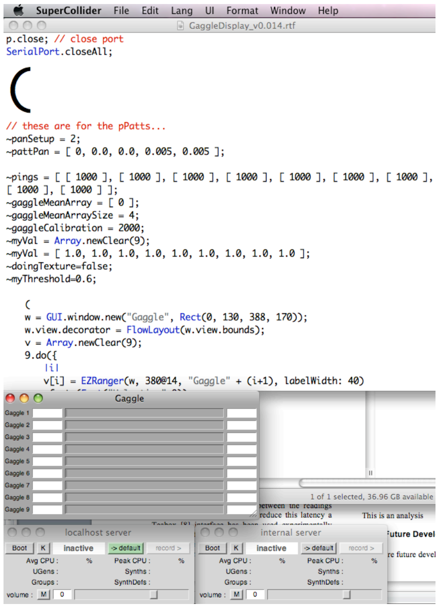

Figure 4 *The SuperCollider coding environment with visual indication of Gaggle activity*

2.1.2. SuperCollider

An earlier musical composition provided the basis for the specifically musical part of the project. *One Hundred and Twenty Seven Haikus* [12] had been prepared for a concert at Kettles Yard Gallery, Cambridge in May 2009. It is an entirely automatic composition, constructed so that it will be 'different' each time it is 'performed' (or perhaps more strictly speaking 'run'). Crucially, however, at each performance it should be as recognisably the same piece as any previous performance, emulating the different but similar performances given by a live performer.

In technical terms, algorithmic, pattern-based processes generate streams of data, which are used to trigger sonic events, timed so as to create a typical time-based musical structure. For instance, a function generates a stream of time controlled values between 0.0 and 127.0 from time x to time y. These values may be used to control sonic events. The sonic events are pre-defined constructions of a variety of unit generators. These unit generators are themselves constructed so that certain parameters are controllable. One stream of values might direct frequency or pitch, another the attack part of an envelope, a third the index of modulation used to determine the voice's timbre. In musical terms, one of the most interesting parts of this process is the way in which the asynchronous control of this number of parameters can create such a 'lively' sound, literally. It is my contention that it is this complex of control that provides the best currently available metaphor for that particular live 'feel' that is created by a live musician.

This is one example of the general interactive blueprint that exists between *Gaggle* and SuperCollider code. The system as described here included a variety of types of interaction. Below is the use each sensor was put to during this particular performance.

1. set the index of modulation depending on proximity;
2. trigger a textural pattern;
3. randomize modulation indices;
4. trigger a haiku (a melodic fragment);
5. trigger a 'finickey' (a melodic fragment);
6. trigger a glissando or slide in a previously sustained sound;
7. trigger a harp-like sound – the pitch dependent on proximity;
8. set the modulation index for this slide;
9. unset for the HCI2009 performance.

None of the above resulted in literal repetition of material, although to arrange this would be trivial. In all case, and most clearly in the cases of 4 and 5 above, (the 'melodic fragments') the triggers involved the real-time development of new, but clearly related melodic material. This emphasises one of the issues of the project involving the investigation of different consequences following use of the relevant metaphor used – and indeed the investigation of what 'rules' might operate in these scenarios.

2.2. The Dancers' Performance

Although urgency was predicated by circumstance, after very little introduction, explanation or description from me the dancers began moving around the device in a most natural and apparently effortless way. As Jane Turner, their choreographer emphasizes,

"I could have a fair bit to say about that as its to do with the improvisational training of dancers, which largely goes unnoticed, as it's about responsiveness and decision making, not necessarily new production, skills in process etc." [personal communication]

The relationship that could be seen developing between the dancers and *Gaggle* puzzled and inspired me; in particular it made me consider other aspects of interaction that might occur. Without any extraordinary prompting from, although under the guidance of their choreographer Jane Turner, they began moving around the space, utilizing the features, such as a large tubular pillar and, during the actual performances, the Festival attendees, building up an interactive space in which their relationship with the unit and their environment could develop. While this in itself was entertaining and delightful, after a few days consideration it occurred to me that the physical behavior itself was as worthy of study as the sounds they were helping to produce. At the same time, it was intriguing to watch the dancers clearly trying to extract from the unit a certain type of response (while also frustrating for me knowing when it wouldn't happen!). These actions tended to be intuitive and abstract. On investigation they could often be seen to be many layered and complex as well as attractive and stimulating to view, suggesting the need for the development of other methods of interaction as well as the modification and expansion of those already existing.

2.2.1. Documentation of Dance Movements

Probably the single most compelling aspect of the process was the fact that feedback was so readily created and available: the dancers 'create' the music they then respond to. In the performance under discussion there's no pure feedback loop as elements of the environment influence their movements as well as the device. Larger gestures were planned during the afternoon entirely in response to the environment, the architecture and the *Gaggle*. Apart from those the dancers' movements were completely abstract; a key element was the way they were attempting to 'communicate' with the device: to find out what it would and wouldn't do. This was both frustrating and interesting as I could imagine sounds and musical gestures that would be appropriate or interesting, but was unable to implement them at the time. Moreover, I hadn't been aware of the possibilities of this sort of interaction while developing the unit over the previous months. In most cases implementation would require the construction of new interfaces made from clusters of sensors along with, of course, the algorithmic software to be controlled. However, many of all gestures documented (as well as many others) suggested further developments both in hardware and software terms and these are discussed in the subsequent section.

2.2.2. Analysis of Dance Movement

Figures 5 to 12 provide images of movements and/or gestures that stood out as particularly appealing in terms of their potential for the development of new interfaces. These 'new interfaces' are not fundamental 'abstract' interfaces (like for example, the piano, guitar…), but instead new compilations of sensing devices and new audio behaviours generated by the data from these devices. The devices, taken as a whole might be considered to be the equivalent of small compositions, one might almost call them toys; they are only designed to have expression through their manipulation by others.

So, figure 5 shows the dancers circling the Gaggle with some velocity, sweeping their arms up and down outlining 'waves' around the unit. An interpretation of this was that the dancers were aware that more movement seemed to mean more audio events (in this they were correct). So, the metaphor used in this particular case was that greater movement means greater sonic activity. The movement reflects the 'design' of the unit in that circling it is the best way of creating movement near it and so generating the movement required of the metaphor. Interestingly, figure 6 illustrates the same movement, but in a different location: a circling motion conducted *away from* the device. The sonic result here was that only a part of the audio material was created in the way that it was from the movements illustrated in figure 5, resulting in a form of echo of that material, but with aspects missing and others radically altered: there was significantly less timbral modulation, for instance. This was quite appropriate metaphorically and worked well in this sense.

In figure 7, dancers can be seen running past the unit individually. On occasion as they pass they jump and clap. The gesture illustrated in figure 11 is almost the reverse of this: smooth movements around the device are occasionally contrasted with sudden gestures of withdrawal. Figure 8 shows them performing in a line gesturing sequentially. There is an interesting balance here concerning the metaphorical nature of the interaction. The dancers were keenly aware of a variety of responses, especially the clearer ones such as proximity effects amplitude. In terms of the interface, does the aesthetic interest come from continued emphasis of this metaphor (and so it's development into a more direct and accepted action over time), or is there more interest, pleasure, whimsy to be gained from the interface design including less predictable consequences?

Figure 5 *Moving in a line, circling the unit, swooping arms above or below the unit*

Figure 6 *Performing away from the unit*

Figure 7 *Sequential group activity: e.g., one after the other, running up to the unit, jumping and clapping, or moving a hand over the unit. Here is an interesting distinction or interpretation: what, if any, difference should there be between running (and walking) and clapping (and moving)?*

Figure 8 *In a line, gesturing*

Figure 9 *Open hands, pulsing*

Figure 10 *Imitating touching, pressing or pointing at (imaginary) buttons/objects, etc.*

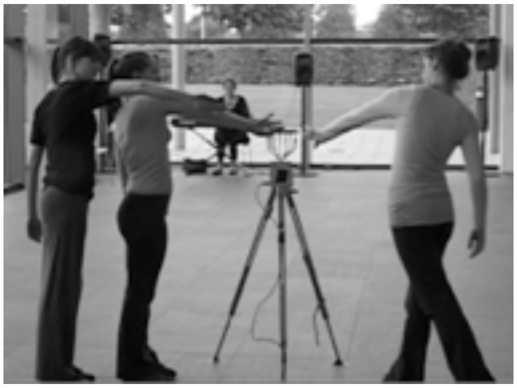

Figure 11 *Sudden withdrawals of the hand*

Figure 12 *Investigating, staring...*

Figures 10 and 12 illustrate the dancers investigating. In figure 10 they are imitating the actions of delegates – frequently looking, staring, pointing, touching. Similarly in figure 12 they are pictured dramatically investigating the *Gaggle* itself.

Two key motivators in this were the attempting control of the sound by physical gesturing (figures 5-9 and 11) and the dramatic 'investigation' of the environment, including the unit itself. The real issue for the use of this analysis of the dancers' own subjective behaviour in this situation and indeed for a composer the really interesting part of the project is the use which subsequent designs of both interfaces and algorithmic responses make of the various physical gestures listed above. It is this mapping which is the metaphor itself and the extent to which actions should correspond or contradict the relevant metaphor is of crucial significance in determining the nature of the resulting work.

2.2.3. Public Interaction

The design of the HCI 2009 Open House Festival [26] meant that throughout most of the event the dancers were able to interact with the delegates. This was built into the performance: at the beginning of each of which the dancers would parade down the main aisle reflecting in a stylized manner some of the movements and actions of the attendees. Some of these gestures were then taken into the performance itself, most obviously 'investigating' and 'pointing' (see figures 10 and 12 above particularly). The set-up of the Festival itself, with delegates able to wander around demonstrations meant that before, after and (perhaps sometimes rather regrettably) during performances delegates were (though sometimes unaware of it) experimenting with the situation, generating interactions with both device and dancers.

Such interactions illuminated a number of issues, including the nature of different performance paradigms and differences between an 'artistic' performance and a technical demonstration.

Also one could see how the fundamentals of human curiosity and how we are encouraged to or inhibited from investigating particular phenomena played their part – some delegates were very much afraid of 'breaking' the device, or of creating something unpredictable and frightening; others were aggressive and had to be actively discouraged from interfering too much with the unit.

The majority, however, interacted in a way that was entirely compatible with the interactions of the dancers themselves, and, as has been mentioned, these interactions did feedback to an extent. These interactions and their ramifications may well inform future developments involving installations developing these ideas (see 3.1.3 below).

2.2.4. Feedback from Dancers

Subsequent to the event the dancers were asked a few simple questions about their experience of interacting with the device. They were informed that the main part of the data regarding this information was already complete: that is, the video recording of the dancing itself. 'Conscious' feedback was also an interesting and important part of this process and would contrast well with the dancing itself – itself containing a less conscious form of feedback. Below is an edited selection of responses.

On Latency/Delay:

"[it] felt impotent at times as I could not accurately identify the sound with the movement through the delay and at other times it was very clear the connections…"

"It was not always completely clear how much our movements were affecting the sound … there was something of a delay between our movements and the sounds made by the device."

On Embodiment and Physicality:

"I really liked being a gaggle of dancers moving with the gaggle of technology - felt like a clear flocking relationship."

"After working with the device it became clearer as to how much influence we were having over the sound… we work very much as a collective and I definitely felt that we worked together in the 'conducting' of the music."

"…I liked the idea of the moving body as an interruption or creating a negative space within an invisible beam, the body creating a negative shape and cutting a connection that then orchestrated sound. [It created a sense] of physical weight, power and presence,"

On the Sounds:

"I thought the choice of music/sounds appropriate as classical music feels to me like a spatially more universal sound than percussive sounds that would perhaps be more direct and local … (this would also be interesting to play with). What I would like to experiment with is to be able to do sharp, quick movement and to hear a direct response to this. I would also like to hear contrasting sounds perhaps sharp sounds amongst the orchestral."

"…As a dancer, I usually respond to sound, however, in this instance I could also influence the sound. "

"The sounds were quite smooth and lyrical which engendered a particular way of dancing. The movements that we created therefore were quite soft and fluid."

On Other Objects:

"…it may be interesting to work with an object that contrasted the beam for example jelly or liquid."

3. FUTURE DEVELOPMENT AND CONCLUSIONS

3.1. Future Plans, Projected Implementations

3.1.1. Sensor Clusters

One of the conclusions to be drawn from these activities is that the number of sensors and transducers employed is crucial. A device employing one or a couple of sensors might be interesting, but is often lacking in significant dimensions of expressivity. A method of attempting to gain expressivity would appear to be the judicious use of many sensors along with suitable algorithmic programming utilising the resulting data. This complex interaction makes fully conscious control difficult and encourages free exploration of the metaphor provided by the device's design. It can be argued that this is one of the more convincing methods of developing interfaces that are analogous to those of acoustic instruments, which have over many years been proven successful.

An Example

An example informed by these findings might be the development of device containing a proximity sensor (e.g. ultrasound), one (or more) touch sensor(s) and a pressure sensor. Touch is an issue in contemporary dance:

"…[it] would be significant to see what they thought of touching technology as opposed to another body that is responsive in a very different way." [27]

There are, of course, many other sensors and transducers available for use in unique combinations. The below outlines one projected function of the device:

1. A sensor registers proximity to the cluster.
2. When the proximity reaches a particular threshold, focus changes to a touch sensor, triggering a certain sound. The proximity sensor is disabled.
3. Focus changes again to a pressure sensor, allowing modulation of the triggered sound. The touch sensor is disabled.

4. Subsequent to the action's completion, the proximity sensor is re-enabled.

3.1.2. Speed of Interaction, Latency and Feedback

The speed of interaction can also be important. One of the things that was clear from the dancers' own reactions and from their written feedback was that there was at times a significant latency in the response. In some situations, a control of events is necessary particularly where it's important to avoid too much audio work for the computers. However, there are times when it is appropriate to use sudden movements, for instance the 'snatching away' or the running, jumping and clapping as documented above. Bearing in mind the fact that different circumstances require different levels of latency it may well be advisable to develop strategies for the deployment of faster but more expensive interfaces for specific interactions.

An associated development involves improvisational feedback: movement creates a result, which in turn influences the movement, and so on. Clearly in order for this to work well latency must in some cases be significantly improved.

3.1.3. Installations

The behaviour of the conference delegates at HCI2009 suggested that there is potential for publicly generated environments such as 'Dark Pool' by Janet Cardiff and George Bures Miller [33], in which various sonic and visual events are triggered with considerable subtlety by visitors negotiating the room: 'an elaborate assemblage of furniture, carpets, books, empty dishes and mechanical paraphernalia. As viewers move through the installation, they activate acoustic components of the work - the silence of the space is broken by strands of music, echoes of stories and fragments of dialogue.' It is planned that objects could be placed in certain environments where they would respond in algorithmic ways to a visitor's movements and interactions. As with the Cardiff/Bures Miller example above, the manner in which one allows and encourages physical involvement which such objects is itself very much a part of the work.

3.2. Conclusions

It is likely that rather than bringing us any closer to understanding the links between human and computer, research activities such as these are going to suggest more questions, more difficulties, more anomalies, more ways of interacting at different levels but without any concrete or easy answers or methodologies. It is intriguing to consider how many of these questions are in 'real life' answered by the limitations of physical reality: is programmability really a curse [13]?

There are also negative aspects to consider and investigate, for instance the lack of precise musical control in the sense of the control one might have of an acoustic instrument. A method for generating, manipulating and modulating the timbre of melodic lines might be interesting and is currently unavailable expect using basic algorithms, but might it be necessary to be cautious about expecting dancers to fulfill the same remit as musical performers? At some point one hopes that the link between music technology and performance will become clearer.

This relates to other more generic questions:

1. Are these performances or compositions?

2. Who are these devices are for? How does/should the conception, design and implementation of a device differ according to the skills of the person it's designed for? Should a musical instrument be designed differently if it's for an 'expert' or a 'novice' and indeed, in the case of a new instrument, what do these terms mean?

3. How important is experience of using the device? Would it help or hinder the performance? How quickly would novelty fade and would this erode enjoyment and expression?

With software tools such as SuperCollider, Pure Data [31] and MaxMSP [32] and hardware tools such as Arduino and the Teabox reaching maturity we seem to be approaching a point where constructing and utilizing such interactions is both technically trivial and affordable, enabling more participants, more experimentation and eventually, maybe, more definitive conclusions concerning the nature of these interactions and indeed the more fundamental interaction between performer and musical instrument.

4. ACKNOWLEDGEMENTS

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