Approaches to Interaction in a Digital Music Ensemble

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ABSTRACT

The Physical Computing Ensemble was created in order to determine the viability of an approach to musical performance which focuses on the relationships and interactions of the performers. Three performance systems utilizing gestural controllers were designed and implemented, each with a different strategy for performer interaction.

These strategies took advantage of the opportunities for collaborative performance inherent in digital musical instruments due to their networking abilities and reconfigurable software. These characteristics allow for the easy implementation of varying approaches to collaborative performance. Ensembles who utilize digital musical instruments provide a fertile environment for the design, testing, and utilization of collaborative performance systems.

The three strategies discussed in this paper are the parameterization of musical elements, turn-based collaborative control of sound, and the interaction of musical systems created by multiple performers. Design principles, implementation, and a performance using these strategies are discussed, and the conclusion is drawn that performer interaction and collaboration as a primary focus for system design, composition, and performance is viable.

Keywords

Collaborative performance, interaction, digital musical instruments, gestural controller, digital music ensemble, Wii

1. INTRODUCTION

The Physical Computing Ensemble (PCE) was formed at the University of California Irvine in Fall 2010 in order to explore the potential of collaborative performance in a digital music ensemble. The hypothesis behind the formation of the PCE was that one approach to a successful DME performance is through highlighting performer relationships and interaction. This paper discusses the guiding principles behind the PCE, the implementation of these principles in three compositions, and the results of a concert of these three compositions on April 22, 2010.

This examination of the collaborative potential of digital musical instruments in a performance context is greatly influenced by the work of musicologist Christopher Small. Small argues that "the act of musicking establishes in the place where it is happening a set of relationships, and it is in those relationships that the meaning of the act lies. They are to be found not only between those organized sounds which are conventionally thought of as being the stuff of musical meaning but also between the people who are taking part, in whatever capacity, in the performance"[16]. Talking about the Princeton Laptop Orchestra, Dan Trueman notes that "[o]ne of the most exciting possibilities afforded by the laptop orchestra is its inherent dependence on people making music together in the same space"[19]. While a rich set of relationships are part of any ensemble performance, a digital music ensemble allows for novel forms of collaborations and ensemble interaction. The Physical Computing ensemble was formed for the purpose of exploring these novel approaches.

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1.1 Collaborative affordances of digital musical instruments

Miranda & Wanderley define a *digital musical instrument* (DMI) as "an instrument that contains a control surface (also referred to as a gestural or performance controller, an input device, or a hardware interface) and a sound generation unit. Both units are independent modules related to each other by mapping strategies"[15]. In their most common form, both mapping and sound synthesis take place in software. This creates opportunites for collaboration due to two factors — the possibility of sharing information with other performers over a network, and the reconfigurability of mapping strategies and synthesis algorithms.

While the possibilities of network-based information sharing in musical performance has been addressed [21] [22], the reconfigurability of DMIs for collaborative performance is equally important. Reconfigurability means that a substantial part of the instrument can change in the course of a performance. This has the benefit that instrument design can become *context-specific*, and can depend on the existence of performers relating to each other in specific ways. While reconfiguring DMIs is not always seen as a good thing, as noted in Perry Cook's Principle "Programmability is a curse"[6], Cook also notes "[more] can be better! (but hard)"[7]. It opens up the possibility for certain configurations of instruments that *depend* on each other, or on certain aspects of the performance environment.

In this paper we refer to a *digital music ensemble* (DME) as an ensemble of musicians performing using DMIs. This restriction of instrumentation is important because it allows for an approach to collaborative performance that takes advantage of the characteristics of DMIs described above.

1.2 Sociological Considerations

Both Small [16] and Trueman [19] observe the correspondence of the development of the western chamber orchestra with the formation of western institutions, with Small making the particular comparison to the rise of western industry. Weinberg notes that "musical networks are based on social organizations, which can be informed by 'social philosophies' "[21]. There is no doubt that the relationships formed within ensembles and also within musical movements are influenced by cultural factors. As Marshall McLuhan notes, technology shapes the formation of culture even as culture shapes the development of technology[14]. It is beyond the scope of this paper to examine the socio-political background of the history of digital music ensembles; rather, an awareness of these factors helped guide the development of the PCE even as the focus narrowed to collaborative possibilities within a DME.

2. PREVIOUS WORK

Describing themselves as a interactive computer network music group, *The Hub*, and before them the *League of Automatic Music Composers*, are notable as the most prominent example of a DME which explicitly focuses on collaborative performance and were interested in "new forms of live music performance that enhance the inherent social attributes of music making"[11]. Influenced by the process-oriented approach of Cage, Tudor, Oliveros, etc. with its emphasis on "allowing rules. . . and performers. . . to determine and shape the nature of music," The Hub employed compositional strategies based on strategies of interaction. For example, in the piece "Is It Borrowing or Is It Stealing" "each player played a melody of his choosing and electronically reported to the group what he was playing, whereupon the other players were free to borrow or steal this melodic information and use it in some way"[5]. In another example, "The Minister of Pitch", different players were assigned control of different musical elements. The musical materials were separated into distinct components such as pitch, rhythm, and timbre, and these distinct components subsequently assigned to the control of different performers. This is called parameterization, and is one of the approaches employed by the Physical Computing Ensemble.

The *Tooka* is an instrument in which collaborative performance is designed into the hardware, whose performers jointly interact with air pressure and bend sensors [10]. The Tooka's designers conclude that using it in performance is a substantially different experience than playing an instrument meant for a single player. The *Soundnet* instrument used by Sensorband is another approach to an instrument whose collaborative nature is designed into the hardware [2]. These instruments demonstrate that collaborative control of an interface is a viable approach, although collaboration through software may prove to be more practical in certain contexts and has the advantages that the mode of collaboration may change during performance, and instruments may also be used in non-collaborative contexts.

Laptop orchestras, and the Princeton Laptop Orchestra in particular, have been important primarily for their use of instruments which are developed by composers and directors [17] [4], in contrast to ensembles like The Hub and Sensorband in which each performer provides and performs with different DMIs [5] [2]. Atau Tanaka's *Global String* [18] and the Beatbugs project [22] demonstrate different approaches to sharing performance data over a network.

Several papers have explored conceptual approaches to collaborative and network-based interfaces[3] [1] [21]; however, further work needs to be done in order to establish principles for the successful design of collaborative digital instruments.

3. FOUNDATIONS OF THE PHYSICAL COMPUTING ENSEMBLE

> The laptop orchestra presents a challenging field of opportunity to both explore the appeals of making music in large numbers — people and their relationships are front and centre in this ensemble — and see what might be possible with new technologies. — Dan Trueman [19]

> Physical computing is an approach to learning how humans communicate through computers that starts by considering how humans express themselves physically. — Tom Igoe [13]

Considering how humans express themselves physically refers to more than just the use of expressive gestures such as hand movements. It also includes the ways in which we position ourselves in space — whether we face each other, move closer and further away from each other — and how this affects the ways in which we use eye contact and subtle physical cues. These physical expressions can be used as the conceptual frameworks for computer-mediated forms of human communication. In this scenario the focus moves away from human-computer interaction and towards human interaction as mediated by a computer.

By focusing on performer action and placement in the physical world, the PCE shares the common sentiment that the correlation between visible performer gesture and sonic result is an important part of musical performance. Chris Dobrian states that "the expressivity of an instrument is dependent on the transparency of the mapping for both the player and the audience" [9]. John Croft has also noted the importance of this consideration in his "Theses on Liveness". Croft states that in order for live performance of electronic music to be meaningful there must be a "causal link between the performer's action and the computer's response" [8].

As the Physical Computing Ensemble took shape it developed the following attributes:

- The performer interface should rely on gestures which would be meaningful to the performer, fellow musicians, and audience.
- Performers should each have their own speaker, which should be positioned on stage as to localize each performers' sound in a different place. However, the performers themselves should not be tied down to a specific location and should use a wireless interface. One corollary of this decision is that performers must not use sheet music, as this would tie them to a location on stage.
- The performers' attention should be on their fellow performers, with interaction being the focus. The performer's instruments should not require visual feedback.
- The role of the computer, and its physical presence, should be minimized in order to direct attention to the performers.
- Each composition should use a different software instrument which utilizes a different approach to performer interaction.

3.1 Technical Notes

Each performer used a Nintendo Wii remote as a gestural controller in the pieces described below. The three-axis accelerometer and trigger button were the only sensors used. OSCulator was used to route the controller data into

Figure 1: The members of the Physical Computing Ensemble in their correct 'stereo' placement

Max/MSP. All of the sound synthesis and compositional programming was done on an intel iMac. We were unable to maintain a consistent connection with six Wii remotes and a single computer's bluetooth, so a second computer was used to receive three Wii remotes' data, which was then routed directly to the primary computer.

The compositions were programmed in Max/MSP and each composition consisted of multiple sections, each with specific parameter settings, including pre-programmed pitch material. Vibrotactile cues using the Wii remotes built-in vibroactuators were given to the performers in order to assist them in navigating the compositions. Three kinds of cues were given: start/stop playing; section change; and specific performance instructions. At the beginning of each section performers were cued as to whether they were playing in a section or not. If they were playing, they received 16 rapid pulses. If they were not they received a single long pulse. Each section was cued with a count-in consisting of 8 eighth-notes, followed by the appropriate start/stop cue at the downbeat of the new section. In "Just Continue to Move" performers also were given specific cues in the form of 1, 2, or 3 short pulses indicating specific musical gestures.

Since there was no visual direction given to the performers in the form of sheet music or visual cues, they were expected to memorize the compositions. In practice, the performers used visual communication with each other to help remember the content of the compositions. The tactile cues also proved to be indispensable. While the Wii remote's vibroactuator is limited to on/off messages the cues were effective in conveying necessary information. The performers had occasional difficulty with distinguishing between different pulse patterns, but this was solved largely through the restriction of cues to certain contexts. There were also some problems with performers not feeling cues, which stemmed from the masking of vibrotactile cues by vigorous physical motion. This did not pose too much of a problem in this context since the tactile cues were primarily used as reminders, and visual communication with other performers easily compensated for missed cues, but it does point to larger issues with the use of vibrotactile systems to provide feedback and guidance during performance.

4. THREE APPROACHES TO INTERACTIVITY

Behind each PCE composition is a different concept of interactivity. The concepts in the compositions examined below are: the parameterization of musical elements, where different musicians are in control of different elements of the same musical event; turn-based collaborative control of sound, where performers share control of a sonic element sequentially rather than simultaneously; and the interaction of systems set in place by each performer. To the degree which these forms of interaction depend upon the capabilities of a computer they are unique to a digital music ensemble. There are other more traditional forms of interaction in these compositions as well, but the success of each piece is dependent upon the qualities of the forms of interaction described above.

4.1 Triangulation

Triangulation is a composition for the PCE which explores the parameterization of musical elements, based on the concept utilized by The Hub in "The Minister of Pitch"[5]. There are three pairs of musicians; in each pair one musician deals primarily with pitch and timbre material and the other musician with rhythmic material. Each musician has a basic sound with which they can perform independently. The pitch musician uses the accelerometer in their Wiimote to draw waveforms in three dimensions. When they hold down the Wiimote's trigger button the change in acceleration in each axis is written into a wavetable. When the trigger button is released, the wavetables are read independently to generate three waveforms which are mixed together and fed to the audio output of the computer. The frequency at which the wavetables are read is pre-programmed into each musical section.

The rhythm musician has a system which is oriented towards rhythmic events. The acceleration in the x- and y-axes of the rhythm musician's Wiimote is read at fixed intervals (generally 16th notes). Rhythmic events are generated at each interval whose maximum amplitude is derived from the accelerometer values. The rhythm musician thus does not determine where the beat is located but rather determines the characteristics of rhythmic events located on the beats. The data from the x-axis is used to create a percussive gated noise sound, while the data from the y-axis is used to control the amplitude of the pitch musicians sound in those sections where the pitch and rhythm musicians are linked.

The first sections of Triangulation consist of rhythm and pitch musicians working independently. In these sections the pitch musicians generate sustained tones and the rhythm musicians generate simple rhythmic patterns. In later sections each pair of pitch and rhythm musicians are linked. When this happens there are three elements to the sound generated by each pair. The first element is the rhythm musician's basic percussive sound which is controlled by the x-axis of their accelerometer. This is unchanged from the sections where the pitch and rhythm musicians work inde-

Figure 2: A pitch/rhythm pair performing in "Triangulation"

pendently. The second element is the sound generated by the pitch musicians. This sound is also unchanged from the sections where the pitch musicians are independent; however, once the musicians are linked the amplitude of the pitch musician's sound is controlled by the rhythm musician's y-axis movements. This works similarly to the way the rhythm musicians generate their basic percussive sound – at fixed intervals the y-axis acceleration is read and this value used to determine the amplitude and duration of a rhythmic event. This rhythmic event is then used to control a gate through which the pitch musician's sound is fed. When the y-axis reading is very small or zero the pitch musician's sound is effectively silent. The third sonic element generated by each pair is the ring modulation of the pitch musician's sound by a sine wave whose amplitude is controlled by the rhythm musician's x-axis. The frequency of the sine wave is randomly selected from {0.5, 0.75, 1.5, or 2} times the frequency of the pitch musician's sound.

4.2 Just Continue to Move

"Just Continue to Move" uses the motions of throwing a ball back and forth as its primary performance gesture. The concept of playing catch has many associations (cooperative play, interaction with the environment, skill-based performance, etc.) Throwing a ball is an expressive act with an infinite number of variations, and is easy to perform but with room for virtuosity. There is a common desire for a form of computer musicianship that is easy for the beginner to grasp but that rewards expert performance[19][1][23]; in some ways catch is a simple example of this.

In the PCE implementation, the virtual ball represents control over a 45 second long sample of a spoken anecdote. Performers grasp the ball by holding the trigger button; while grasped, acceleration controls the amplitude of the sample. When the ball is thrown by releasing the trigger button momentary acceleration and angle of release are measured. A short section of the sample whose end is the playback position of the sample at the moment of release is then looped. The release angle is mapped to the beginning time of the loop, from 200-800ms before the time at the moment the ball is released. Acceleration is mapped to the playback speed of the sample from a range of 100-200%. A leak is then introduced to the playback speed such that it takes 10 seconds for the sample to slow from a maximum speed of 200% to 25%, at which point the sample is stopped. The result is a pseudo-doppler effect which aurally conveys the trajectory of the ball.

In performance, the physical location and action of the performers combines with the sonification of the ball's trajectory to inform the performers of the appropriate actions. A full range of catch gestures is employed, including long-bombs, close volleying, and feigned throws. The actual performance followed a predetermined arc, but there was considerable room for personal interpretation; the transparency of metaphor and mapping allowed the performers to have fun and improvise, with enjoyable results.

4.3 Skipping Stones

In "Skipping Stones" individual musicians create musical events whose qualities are derived from the metaphor of skipping stones on a lake. The musician makes a single motion — picking up a stone by pressing the trigger button, throwing the stone by moving their hand perpendicularly to the ground, and releasing the stone at the proper place in the throw by letting go of the trigger button. This single motion creates a miniature musical system whose characteristics are determined by the acceleration and angle at the moment of the stone's release. How hard the stone is thrown determines the speed, amplitude, and number of repetitions, or 'skips', of a note. The angle of the stone's release determines the length of the sonic event which constitutes each skip. There is a metric pulse and each skip is one of eight rhythmic subdivisions of the basic pulse, from a 32nd note to a half note. While the subdivisions are quantized, the moment of release is not, which allows for considerable rhythmic flexibility.

The primary form of interaction in this composition is in the creation of systems with different rhythmic subdivisions. Depending on how many musicians are playing at once this takes the form of a duet with easily discernible interlocking rhythms or it can take the form of a complex composite of many different rhythms. In contrast to the processes in a typical algorithmic composition, whose parameters are set before the composition begins, in "Skipping Stones" the parameters of the process are set by a gesture extremely similar to a traditional performance gesture. This allows performers to set into motion musical processes which are a reaction in real-time to the processes created by other musicians.

5. IN PERFORMANCE

Since one of the goals of the PCE was to highlight the physical relationships between performers, the staging of each composition was important consideration. The stage setup consisted of six speakers in a semi-circle behind the ensemble, and a large open space for the performers to inhabit. Each performer had a dedicated speaker which served as their home base. This influenced the performers' location left-to-right more than front-to-back, in an attempt to locate each performer in the correct location in the 'stereo field'.

Each composition employed varying ensemble configurations ranging from duets to tutti sections. Specific stagings were established in order to highlight the interaction of each configuration. This helped to convey the focus of the composition to the audience and facilitate visual communication between performers. Different stagings also served to suggest different kinds of performance gestures. For example, in "Just Continue to Move" duets in which performers were located at opposite sides of the stage caused the performers to throw 'long bombs', while stagings in which the performers were close more often instigated volleying. The fluidity of the staging was a hugely important factor in the

Figure 3: Performers playing catch at either end of the stage

performance, with the open space allowing the performers considerable latitude in physical expression.

5.1 Musical Results

In order to highlight the physical relationships and interaction of the performers, severe limitations were placed on the design of the instruments and compositions. The ensemble consisted of six UCI Masters students: four musicians, one artist, and one choreographer. As an informal, volunteer ensemble the PCE faced familiar challenges such as limited rehearsal time and performers who were unfamiliar with digital musical instruments. Limited rehearsal time meant that the instruments needed to make sense to the performers quickly, and the compositions needed to contain simple performance instructions. Rehearsals were mostly conducted in one-on-one instruction and smaller groups. There were two full ensemble rehearsals in the performance space, during which the staging was worked out.

During the rehearsals it quickly became apparent that the intuitive nature of the performance gestures made it easy and fun to learn the instruments. The open-ended nature of the catch metaphor in particular led the performers to have fun experimenting with different performance approaches. The instruments in "Triangulation" were more difficult for the performers to master. In particular, drawing wavetables proved to be a conceptual challenge, partly because of the difficulty of conceptualizing the audible results of different gestures, and partly because the effect of the drawing was not heard until the gesture is completed. After a few rehearsals the performers overcame these difficulties, and in performance the audience had little trouble correlating the gestures and the sound.

Learning the compositions was more difficult, as the musical material was substantially different than the performers had previously experienced and there could be no visual directions on-stage. Several performers ended up writing 'cheat sheets' on their palms to assist them in remembering forms, but for the most part visual communication between performers compensated for any momentary lapses of memory.

The actual performance was a lot of fun for performers and audience alike. The compositional and technological simplicity enabled the performers to concentrate on interaction and helped them maintain a strong connection with the music. The biggest factor in the evening's success, however, was the comfort level of the performers and the ways in which they expressed their personalities onstage. This took the form of individual performance styles and dynamic ensemble interaction.

6. FUTURE WORK

This paper presents three approaches to human interaction in a digital music ensemble. Different approaches have been taken by other DMEs, and there remain many unexplored possibilities. Several theoretical frameworks have been proposed in order to guide effective interaction design[21][1], and a dimension space for evaluating collaborative music performance systems has been proposed [12]. However, further research is needed in order to develop effective strategies for musical collaboration using DMIs.

6.1 Intermediate Mapping Layers

Intermediate mapping layers have been proposed as a way of reducing the amount of re-mapping when changing the interface or synthesis algorithm of a DMI.[20] Synthesis parameters may be mapped to perceptual variables, for example, which are then mapped onto synthesis parameters. This suggests the possibility of creating layers to support collaborative performance. A mapping layer would be created which incorporated a particular approach to collaboration. Sensor data from two input devices would then be mapped to the input of the mapping layer, and the output of the layer would be mapped to synthesis parameters. Additional mapping layers could be incorporated between the collaborative layer and the input device or sound synthesis. The benefit of this approach is that different strategies for collaboration could be quickly implemented into preexisting DMIs.

6.2 Musicological Study

The concept for the Physical Computing Ensemble came from the consideration of the role of relationships in musical performance. While the implementation of the PCE focused on technical issues of collaboration, it does not address the sociological implications of DMEs. The emergence of standard approaches to laptop orchestras and the institutionalization of DMEs in academic settings creates an opportunity for a closer examination of these implications. One place to start might be to take a closer look at the role of the San Francisco area's counter-cultural movements in the formation of the League of Automatic Composers and the Hub.

7. CONCLUSIONS

The hypothesis asserted in this paper is that one approach to a successful DME performance is through highlighting the relationships and interaction of the performers. During the creation of the PCE considerations which would normally be the primary focus of a performance, such as compositional intent and the expressive facility of individual performers, were de-emphasized in order to focus on the development of collaborative strategies which the performers would be able to confidently employ. Careful attention was given to the clarity of performer's instrumental gestures, and to the correlation between these gestures and the musical result. Our hope was that this approach would culminate in a performance that was understandable, engaging, and enjoyable.

The April 22 performance was to an audience of around 80 people who were largely unfamiliar with electro-acoustic music. Once the performance began it quickly became apparent that they weredrawn in by the rapport between the performers. By the end of the concert it was apparent that our first two hopes, that it be understandable and engaging, were fulfilled. Anecdotal evidence gathered over the next week suggests that the third hope was fulfilled as well.

While it is difficult to quantify precisely, it is our belief that the principles laid out in this paper were instrumental to the concert's success. Certainly there was also a novelty factor as well due to the use of Wii remotes as the control interface. It may be that an audience who is more familiar with electro-acoustic music might also have been more rigorous in their aesthetic critique. Nonetheless, we believe that we have demonstrated the viability of an approach to digital music ensembles that focuses on collaborative music performance.

We would also like to emphasize that the reconfigurability of digital musical instruments provides an opportunity for modes of collaborative performance practice to be implemented on a wide variety of instruments. In the concert described above, the use of different collaborative approaches to give each composition a distinct character was greatly beneficial. However, there still remains much work to be done in establishing principles for the successful design of collaborative instruments and the creation of tools to facilitate their implementation.

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