Interactive Lighting in the Pearl: Considerations and Implementation

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ABSTRACT

The Pearl is a multi-modal computer interface initially conceived as an interactive prop for a multi-artistic theatrical performance. It is a spherical hand-held wireless controller embedded with various sensor technologies and interactive lighting. The lighting was a key conceptual component in the instrument's creation both as a theatrical prop and also as an interface for musical performance as it helps to address conceptual challenges and opportunities posed by the instrument's spherical form.

This paper begins by providing a brief description of the Pearl and its use as a spherical instrument. We then discuss mapping the Pearl both to generate sound and control its interactive lighting, and identify different strategies for its use. Strategies we identify include feedback regarding performer gesture, information about the state of the instrument, and use as an aesthetic performance component.

Author Keywords

NIME, multi-modal, interactive lighting, mapping, sphere

ACM Classification

J.5 [Computer Applications] Arts and Humanities — Performing Arts H.5.5 [Information Systems] Sound and Music Computing — Systems

1. INTRODUCTION

The Pearl is a multi-modal computer interface initially conceived as an interactive prop for an multi-artistic theatrical performance. As a musical instrument it is conceptually simple, yet presents challenges in both design and manufacturing as well as in the conception of its use.

The Pearl was designed for use in a theatrical production created by composer David Coubes and percussionist Krystina Marcoux. The production is an adaptation of John Steinbeck's novel *The Pearl* created for two performers, a dancer and a percussionist, and was premiered on March 27, 2015. As the centre of the plot the Pearl becomes almost a third character in its own right, a fact which led to the desire for an interactive prop which could be programmed to respond appropriately over the course of the show. In

Figure 1: A Pearl resting on its charging base.

addition, as the show is conceived as a multi-artistic production in which both the main performers act, dance, and perform music, it made sense that the Pearl would also be able to fulfill a multi-functional role.

The initial conception of the Pearl necessitated that its visual aesthetics would play a dominant role in its creation. The inclusion of individually addressable LEDs allow for complex lighting variations to be created. The visual appearance and composition of the resin shell also plays a key role in the visual aesthetics. In addition, it was important that the Pearl be a monolithic, enclosed object, appearing as a wondrous object in accordance with its role in the story.

2. SPHERICAL INTERFACES

There is no shortage of computer interfaces/displays which take the form of a sphere. The simplest implementation is as a handheld device utilizing inertial sensing for their primary interaction and with either no lighting or a single light source. For example, Panagiotis Tigas created the *Sonicsphere*, a palm-sized sphere containing a wireless transmitter and accelerometer [9] . In this instrument discrete orientations are mapped to pitches, with the pitch being triggered upon the transition from one orientation to another. Antonsen and Bjerknes created interactive juggling balls, consisting of white spheres lit internally with multi-colored LEDs and containing an inertial measurement unit.[1] One mapping of these balls detects when the balls are in mid-air versus being held by the hand, and changes the lighting of the balls accordingly. The Orb, a similar DMI inspired by

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[1] `https://www.youtube.com/watch?v=rXp2sXKVB58.`

Figure 2: The Pearl used in the production "La Perle," with dancer Bryan Eliason and percussionist Krystina Marcoux. Photo by Julien Leroy.

balance juggling, in which a "performer moves a ball around the body in smooth, rhythmic motions," was conceptualized and prototyped at IDMIL by Gregory Longo [6] . In addition to multi-colored LEDs and an accelerometer the Orb incorporates a piezo-electric sensor for knock detection and an IR distance sensor allowing for interacting with the space around the instrument.

Several larger interactive spheres have been created by the DMI community. Mailis Rodrigues created the *Intonaspacio* as a controller for interacting with site-specific media installations [12] [8] . Roughly 30cm in diameter, the Inonaspacio incorporates several piezo sensors for sensing taps and strikes, an IR sensor for sensing the distance between the sphere and the performer, an IMU, and a microphone which is used for capturing audio in the space which is used both as source material and as a source of control data. The *AlphaSphere* is a spherical device which is mounted on a table-top stand [11] . As a non-held device it does not contain an IMU but instead utilizes an array of 48 pressure sensitive pads located around the surface of the sphere.

The *Sphero* is a remote controlled sphere with an internal motor allowing it to be driven freely [7] . Slightly smaller than a baseball the Sphero contains an RGB LED which is used to communicate system status. In several ways the implementation of the Sphero is similar to that of the Pearl, including its size, communication strategy, and implementation of inductive charging.

3. TECHNICAL DESCRIPTION

The Pearl is a spherical instrument consisting of a 3D-printed central structure embedded within translucent cast resin. The resin is pigmented in various ways in order to create a striated visual appearance as well as to aid in diffusion of the embedded lighting. The centre of the Pearl contains modules consisting of sensors, lighting, wireless communi-

cation, battery/power management, and a central microcontroller. The microcontroller is an 8-bit ATMEGA328p running at 8MHz. Due to its limited processing speed it was necessary to closely manage the timing of the different modules. We will discuss the impact of that in the various sections below.

Three versions of the Pearl have been created so far. The first two versions are 8cm in diameter, while the 3rd version is 10cm in diameter. The pigmentation of the resin shell varies between the versions as we are still researching the best approach for creating the preferred opacity and striation of the Pearl. The first 8cm Pearl was delivered to the performers in early February in order to allow for pre-production and publicity of the show; the second 8cm Pearl was delivered in early March to serve as a backup during the performance. The 10cm version was created as an experiment with a larger form factor.

3.1 Electronics implementation

The Pearl contains four types of sensors. Inertial and position sensing is carried out by a 9DoF MARG sensor consisting of an accelerometer, gyroscope, and magnetometer. The MARG sensor also contains an embedded temperature sensor. Two piezo-electric sensors are embedded within the resin on opposite sides of the Pearl. Two IR emitter-receiver are also embedded within the resin, orthogonal to the piezo sensors.

The interactive lighting system consists of 24 RGB LEDs mounted in six strips of four along the circumference of the Pearl's inner structure. Each LED contains an integrated WS2812 IC which communicates with a 1-wire protocol which requires precise timing of the serial signal.

The AD conversion of the piezo sensors takes place within an interrupt loop with a nominal frequency of 2kHz and the magnitude is taken and peak values stored for the next serial transmission. The same loop samples the IR sensors as well as the voltage of the battery at 33Hz. IMU data is read over I2C at 100Hz. Lighting control and sensor data transmission are also scheduled to occur at 100Hz, and serial data input at 33Hz.

All of these processes are also driven by interrupts, and the interaction between them causes the timing at which the processes occur to vary considerably. This is most noticeable in two ways. First, despite sampling at 2kHz percussive impulses on the surface of the Pearl produce inconsistent sampled values. One possible explanation for this is if an impulse occurs when a different interrupt is in process. In that circumstance the sampling of the piezo signal will be delayed until the other process is completed.

A second consequence of timing issues occurred when the performers requested the implementation of a strobe-light function. Once implemented it was immediately visually apparent that the speed of the strobe was inconsistent due to the many concurrent interrupts being called. To reconcile this the sampling of the piezo sensor is disabled when the strobe function is activated. Following that step the timing of the strobe function was satisfactory.

4. MAPPINGS

The development of the Pearl took place independently of the production of the show. While discussions were held to determine the overall direction of its development, the functionality of the Pearl as developed at IDMIL and that utilized for the show was significantly different. Here we will discuss briefly mappings which were created at IDMIL.

4.1 Mapping 1

The first mapping was developed with a prototype of the Pearl which lacked piezo and IR sensors and consists of two synthesis blocks. The first was based on the Granular Toolkit for Max/MSP by Nathan Wolek [14] and utilizes three granular synthesizers utilizing different source audio files. Parameters of the granular synthesizers such as grain location, dispersion, and length are mapped to the orientation of the Pearl. The amplitude of each synthesizer is mapped to the leaky integration of the derivative of one axis of rotation. So as the Pearl is rocked around one axis the amplitude of the synthesizer mapped to that axis increases. In practice, changing the orientation of the Pearl while rocking causes a crossfade between different granular synthesizers. Overall, this synthesis block is programmed to be highly sensitive to small motions.

The second block is programmed to more less sensitive, and thus only apparent during larger performance gestures. For this block the magnitude of acceleration for each axis is mapped to the amplitude of a waveshaping synthesizer.The magnitude of modulation is a combination of orientation as well as magnitude of acceleration.

4.2 Mapping 2

The second mapping developed utilizes a synthesizer consisting of a signal chain consisting of a white noise source, resonant lowpass, waveshaping filter, and digital delay. Broadly speaking, the magnitude of the piezo signals control amplitude of the signal split to both the delay and the DAC as well as the magnitude of modulation, the orientation controls the waveshaping function, filter parameters, and delay parameters, and acceleration magnitude controls feedback and amplitude of the digital delay (which is set to cascade into feedback during high accelerations).

4.3 Interactive Lighting

The Pearl does not contain mechanically moving parts which might serve as indications of the state of the instrument, or visual markings to convey its orientation. In this case interactive lighting provides the opportunity to provide compensating visual information to both the performer and observer. Three possible uses of interactive lighting in this context are to display information regarding the state of the performance system, to convey information regarding performer gesture, or to add aesthetic elements to the performance.

4.3.1 Lighting and Instrument State

The display of information to display system state or information gathered by the system is common in digital devices. In the same fashion, many DMIs utilize interactive lighting to indicate the status of the system. In computer music performances this frequently takes the form of displaying information that is either sequenced by the performer or generated algorithmically by the computer in response to performer input. A notable example is the Monome controller, which has spawned a series of similar controllers consisting of grids of pushbuttons with integrated lighting [5] . In these instruments it is common to use interactive feedback to display currently activated steps of a step sequencer, as well as a moving strip of lights which indicates the sequencer's temporal location.

The Yamaha Tenori-On is a similar instrument which adds a secondary grid of LEDs on the back of the instrument which mirrors the grid on the front of the instrument [10]. The creators of the Tenori-On note that its construction is intended to make you "understand the musical structure visibly." In this case we can see that displaying the system state to the audience as well as the performer can be helpful in performance.

4.3.2 Performer Gesture and Aesthetics

Interactive lighting can also be used to display information regarding performer gesture. It may be more effective if this information is not already visible within the performance gesture - however, this distinction is not necessarily static. Consider the Laser Harp, for example, which triggers notes when a hand blocks a laser beam and is a highly visual spectacle.[2] When the performer moves her hand to block the laser the important information regarding triggering a note is already contained within the performer's arm movement. We could then consider the visual impact of the laser beam being blocked as an aesthetic addition. However, when performing in front of large numbers of people, or in a situation where the performer isn't well-lit, the audience perception of the performer's arms may be impaired. In this case the visual impact of blocking the beam provides fundamental information regarding performer gesture.

4.3.3 Lighting Implementation in the Pearl

We have implemented a variety of approaches to implementing interactive lighting in the Pearl. One approach is to visually display control signals generated by performer gestures. In this way small performance gestures, which may or may not be perceptible to the audience, can nonetheless be made visible. Examples from the mappings above include both small rotations and small rubbing or scraping gestures. These small gestures contrast with larger gestures which may be used to generate amplitude control signals. One implementation consists of a two-stage lighting mapping, in which a base lighting level is generated by amplitude levels (which tend to have relatively long decays in the mapping we describe) while rotation generates a brighter light of a similar colour but with a much faster decay.

Lighting can also be used to display key information which may not be visible at all in the physical instrument. When using absolute orientation using a sphere, for example, there can be no way to know which orientation corresponds to neutral in any of the three axes. One way of helping is to use the lighting to provide landmarks – marking one side of the sphere as the 'top,' for example. Another way is to use different colour schemes for the sphere to indicate its general orientation. In one of the Pearl mappings, for example, different synthesis processes would be activated depending on the orientation of the sphere. For each orientation a base colour is generated, in which all of the LEDs assume a particular colour. By linking the orientations to different base colours it is possible to show the current orientation. This has the benefit not only of providing information to the performer but also to demonstrate correlations between the instrument's state and the sonic results of the performer's gestures.

5. DISCUSSION

When implementing an interactive lighting system in a digital musical instrument it can be helpful to take into account many of the same considerations we would give to the relationship between performer gesture and sonic result as we go from considering a two-dimensional gesture-sound mapping relationship to a three-dimensional gesture-sound-lighting relationship.[3] Due to this fact it makes sense that we should be just as concerned that the lighting bear some

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[2]http://jeanmicheljarre.com.

[3]As in Bert Bonger's depiction of human-machine interaction [1].

kind of correspondence to both the performer gesture as well as the sonic result. Similarly, we should be concerned that the visual result of performer gesture be synchronous with both the sonic and gestural components, as well as sharing some energetic and morphological characteristics.[4]

In some sense it may be that this three-dimensional relationship shares certain burdens between both sonic and visual response to performer gesture. For instance, some kind of feedback can be helpful in order to give both performer and audience confidence that the performer's gestures have been recognized by the system. In a gesture-sound mapping where the system response is not instantaneous, for example, visual feedback may help make clear that that response is intentional. Such is the case in an instrument like the Monome discussed above, in which the performer enters steps into a sequencer asychronously from the sequencer's actual temporal location.

There may also be possibilities for the use of lighting to enhance the visual communication of performer gesture.[5] On the one hand, large performer gestures, of the kind that already clearly display performer expressivity, may not benefit from complex visual responses – or it may be that certain extreme lighting effects during these moments can help make them over-the-top in a theatrical sense. On the other hand, small performer gestures of the sort that may not be readily discernible to the audience may benefit from carefully programmed visual responses.

6. CONCLUSIONS

The work presented in this paper demonstrates ways in which an interactive lighting system can enhance certain aspects of performance on a digital musical instrument. The spherical form and materials of the Pearl create a relatively featureless exterior which, combined with the extensive use of orientation sensing, limits the visual cues regarding performer gesture and instrument state. The use of interactive lighting presents one approach to solving this problem.

In the discussion above we hope also to highlight the potential of interactive lighting to usefully complement the gesture-sound mapping paradigm. While it is tempting to implement wholly pragmatic lighting schemes in which we duplicate visual cues contained within performer gesture, there are many other possibilities for using an interactive lighting system. Making visible the subtle qualities of small performer gestures, for example, or displaying information regarding the state of the instrument which would would not be inherently visible.

Challenges encountered during the creation of the Pearl led to the research described above, and we view the Pearl as an excellent platform for a continued exploration of the implementation of interactive lighting systems. Of particular interest to us is research into the ways a system like the Pearl can help communicate performer intention and action during computer music ensemble performances. In these situations the challenge of associating each performer's gesture and the resultant sound is heightened, and the use of interactive lighting to make the results of performers' gestures explicit may prove helpful.

7. ACKNOWLEDGMENTS

8. REFERENCES

[1] B. Bongers. Physical Interfaces in the Electronic Arts: Interaction Theory and Interfacing Techniques for Real-time Performance. In M. M. Wanderley and M. Battier, editors, *Trends in Gestural Control of Music*, volume 6, pages 41–70. Ircam, Paris, 2000.

[2] J. Croft. Theses on Liveness. *Organised Sound*, 12(01):59–66, Apr. 2007.

[3] S. Dahl and A. Friberg. Visual perception of expressiveness in musicians' body movements . *Music Perception: An Interdisciplinary Journal*, 24(5):433–454, 2007.

[4] J. W. Davidson. Qualitative insights into the use of expressive body movement in solo piano performance: a case study approach. *Psychology of Music*, 35(3):381–401, July 2007.

[5] J. Dunne. Review: Monome 40h Multi-purpose Hardware Controller. *Computer Music Journal*, 30(2):30–32, 2007.

[6] G. Longo. The Orb: Wireless Interface for Motion Based Control, 2007. IDMIL Research Report. http://greglongoproductions.com/orbfinalpaper.pdf, accessed April 15, 2015.

[7] C. Bonnington. Review: Orbotix Sphero 2.0. *Wired*, 2013. http://www.wired.com/2013/08/sphero-new/, accessed Feb 1, 2015.

[8] C. R. Mamedes, M. M. Wanderley, and P. Ferreira-Lopes. Composing for DMIs - Entoa, music for Intonaspacio. *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 509–512, 2014.

[9] T. Murray-Browne, D. Aversano, S. Garcia, W. Hobbes, D. Lopez, T. Sendon, P. Tigas, K. Ziemianin, and D. Chapman. The Cave of Sounds: An Interactive Installation Exploring How We Create Music Together. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 307–310, 2014.

[10] Y. Nishibori and T. Iwai. TENORI-ON. In *Proceedings of Conference on New Interfaces for Musical Expression*, pages 172–175, 2006.

[11] A. Place, L. Lacey, and T. Mitchell. AlphaSphere. In *Proceedings of Conference on New Interfaces for Musical Expression*, pages 491–492, 2013.

[12] M. Rodrigues, M. M. Wanderley, and P. Ferreira-Lopes. Intonaspacio: A digital musical instrument for exploring site-specificities in sound. In *Proceedings of CMMR*, Marseille, France, 2007.

[13] D. Wessel and M. Wright. Problems and Prospects for Intimate Musical Control of Computers. *Computer Music Journal*, 26(3):11–22, 2002.

[14] N. Wolek. Granular Toolkit v1. 0 for Cycling74's Max/MSP. *Journal SEAMUS*, XVI(2):34–46, 2001.

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[4]For more discussion of these correlations see [2] [13].

[5]See [3, 4] for more on visual perception of musical expression.