Thrii

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ABSTRACT
Thrii is a multimodal interactive installation that explores levels of movement similarity among its participants. Each of the three participants manipulates a large spherical object whose movement is tracked via an embedded accelerometer. An analysis engine computes the similarity of movement for each possible pair of objects, as well as self-similarity (e.g., repetition of movement over time) for each object. The extent of similarity among the movements of each object is communicated by a visualization projected on a three-sided pyramid, a non-directional audio environment, and lighting produced by the spherical objects. The installation's focus is intended to examine notions of collaboration between participants. We have found that participants engage with *Thrii* through exploration of collaborative gestures.

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**]: *Collaborative computing, Synchronous interaction.*

General Terms
Algorithms, Design, Human Factors.

Keywords
generative video; generative audio; dynamic time warping; tangible objects; movement similarity.

1. INTRODUCTION
Thrii is a multimodal interactive installation that was designed to investigate movement similarity among its participants, as exhibited through their interactions with three large, LED-embedded, spherical objects. Conceptually, this initial iteration of the installation is intended to examine notions of collaboration between participants.

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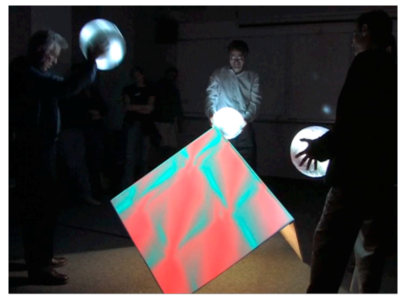

Figure 1. *Thrii* is a multimodal interactive installation that explores similarity of movement among its participants.

A participant's movement is sensed using a Wii remote embedded within each spherical object. Each Wii remote sends raw accelerometer data to an analysis engine, which determines in real-time the similarity of movement for each possible pair of objects, as well as self-similarity (e.g., repetition of movement over time) for each object. Both paired similarity and self-similarity are computed over a history of time, using a real-time adaptation of Dynamic Time Warping and Edit Distance algorithms. A projected visualization, an immersive audio environment, and the three interactive objects' lighting communicate the extent of similarity among participants' interactions with the spherical objects and each other. The central focus of the installation is for the participants to explore the explicit visualization of similarity between pairs of objects; this visualization is projection mapped onto a centrally located pyramid, and uses color to indicate levels of similarity at different instances in time. The audio environment communicates similarity between pairs of objects as well as more complex relationships among all three objects over time.

Simple geometric forms were presented in groups of three throughout the design. The installation includes three spherical objects, three hemispherical speakers, and a three-sided symmetric pyramid. Three participants can each actively affect the system by interacting with one of three hand-held spherical objects. The intent behind having three participants affect the system is to encourage both similarly and dissimilarly paired interactions. With only two participants, similarity and dissimilarity could not be explored concurrently.

Because the interactive feedback is based upon the relationships between the hand-held spherical objects, it provides an incentive for collaborative participation. Some participants explored coupling a sequential ordering of movements to achieve a series of unique patterns within the visual projection. These types of ordered collaborations observed from user interaction with *Thrii* have directed our group's future work to expand the project for collaborative learning applications among multiple users.

2. PRIOR WORK

In creating this project, we looked in to a number of existing artistic works for guiding principles. In particular, we looked at interactive works containing these specific qualities: (1) straightforward feedback based on participants' movements; (2) feedback based on participant interrelationships; and (3) attractive and engaging use of light, color, and sound. The goal was to visually and audibly illustrate body movement and participant interrelationships, thereby creating a natural feedback cycle that would encourage certain responses. We do not directly elicit these responses; they are intended to emerge naturally through system interaction.

Influential works included Scott Snibbe's "Boundary Functions" [10] where participants are separated from other participants in the space by dynamically shifting lines projected on the floor. This simple system allows individuals to explore the boundaries of their personal space in a direct and illuminating manner. Brian Knep's "Healing Pool" [5] visualizes a biological space where participants 'wound' the space simply by moving around in it, and the virtual tissue slowly heals and knits itself back together using a simple, yet attractive and engaging biological function. We also looked at the lighting work of Olafur Eliasson and James Turrell's "360° Room for all Colors" [2]. Eliasson uses deeply saturated walls of changing light to create an immersive experience of color and time. James Turrell's work is inspiring because he uses only light, shapes, and color to create intensely moving, calming, and mesmerizing spaces.

The design of our system includes a number of existing hardware and software technologies [1][3][6][7][8][9][12].

3. METHODS

Thrii includes a number of distinct components: tangible spheres, analysis, audio feedback, and visual feedback.

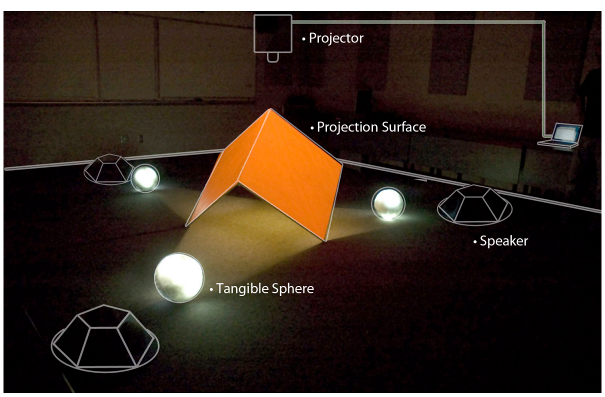

Figure 2. Key Physical Components of System.

Users of the system interact directly with the spherical objects (e.g. by holding them and moving them, passing them between each other, rolling them on the floor). The movement is sensed and sent via Bluetooth to the analysis component. The analysis component computes a number of features based on the movements and their relationships. Relevant features are then sent via Open Sound Control to the audio and video feedback components, which sonify and visualize the data. In addition, the analysis component updates the lighting in each spherical object.

3.1 Tangible Spheres

The tangible spheres are the main input component of the system; the users' movements are sensed as they manipulate the objects. The objects also provide lighting both for aesthetic purposes and to convey similarity information.

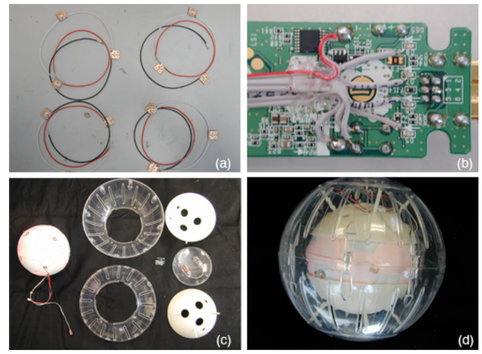

Figure 3. Spherical Objects design overview.

Each object is constructed from the main circuit board of a Wii remote, secured within a foam ball, and embedded within a 10-inch plastic gerbil ball. The large size of the gerbil balls encourages large movements by the participants, which facilitates imitation and mimicry between participants. The Wii circuit board is used for its accelerometer, Bluetooth connectivity, and LED control signal functionality. The accelerometer senses the movement of the object, and communicates with the rest of the system over Bluetooth. Each of the four Wii remote LED outputs are hacked to control a set of three high intensity LEDs distributed across the surface of a foam ball. All components are powered by an 11.1V 3000 mAh Lithium Poly battery via custom circuitry.

Among the four LED sets, one set remains lit to indicate the north pole of the object and to contribute to the dim ambient lighting of the room. The remaining three LED sets are used to indicate when two objects move synchronously. When an object moves in synchrony with another object, all of its LED sets light up and they both fully glow. It was found during this iteration that turning on all LEDs at once has the greatest visual impact for indicating real-time movement similarity. The diagram in Figure 3 shows: (a) Four LED arrays are connected to (b) the four LED control outputs from the Wii remote. (c) Major exterior components of tangible sphere dismantled and (d) assembled.

3.2 Analysis

Accelerometer data sent via Bluetooth from each object is received by the analysis component. The analysis component is responsible for computing in real-time the pair wise similarity of movement for objects and self-similarity for one single object (e.g., repetition of movement over time).

The similarity measures are computed over longer periods of time, but are based on underlying momentary similarity measures. These measures compare the movement of one object at time *t1* with the movement of another object at time *t2*. The system allows one of many underlying similarity measures to be used (e.g., the similarity in the magnitudes of acceleration of two objects, or the similarity in the overall 3D acceleration vectors).

For this installation, magnitude of acceleration similarity is used because that particular similarity measure is not influenced by the orientation of the object and the spherical objects do not imply any particular orientation.

To perform the analysis, we extended the AME Patterns Gesture Recognition Library and its ofxPatterns openFrameworks add-on. The algorithm compares the movement of two Wii remotes as a real-time adaptation of Dynamic Time Warping and Edit Distance algorithms. The accelerometer data is sampled at 50Hz, and the analysis is performed on the most recent 300 frames (6 seconds). This is implemented with an efficient O(n) complexity, where n is the history size. The efficient implementation allows for simultaneous comparison of multiple pairs of Wii remotes. In addition to the raw similarity analysis, we also compute a FFT of a subset of the similarity data, which exposes frequencies at which movement is repeated (either between a pair of Wii remotes, or within one Wii remote).

3.3 Projected Visual Feedback

Visuals are projection-mapped onto a three-sided pyramid. Each panel of the pyramid compares the similarity between two tangible spheres and visualizes the output of the adapted analysis Dynamic Time Warping and Edit Distance algorithm. For a given unit of time, the current acceleration value for each object is compared to the current acceleration of a second object, as well as the second object's history of acceleration. This results in a 2D matrix of similarity values, in which each similarity value is mapped to a pixel's color value through a three-color gradient. The 2D matrix of pixels creates a dynamic texture that documents the history of similarity over a window of time (see Figure 4)

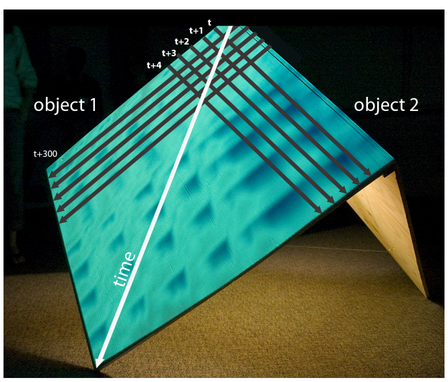

Figure 4. A 2D matrix of pixels creates a dynamic texture that documents the history of similarity over a window of time.

Because there are three interactive objects, three textures are produced for each pair. The analysis for self-similarity is not visualized, but is utilized by the audio feedback. These textures are projected on the pyramid so that one participant interacting with object 1 can see real time and history of similarity with object 2 and object 3.

3.4 Audio Feedback Environment

The audio feedback sonifies complex aspects of similarity among the three objects. There are three musical sections, examples of which are linked below. Our first section represents stillness. It is a textured sound without much high frequency content, reminiscent of underwater creaking noises. The audio feedback returns to this section whenever there has been no activity in the space for at least ten minutes. This section is designed to be more surreptitious than the other two sections, as it can fade into the background and become unnoticed. Once any of the tangible objects is moved, the audio feedback begins to cycle between sections two and three, each lasting three minutes, until the objects become stationary again, whereupon the first section returns.

The second section is designed to explore movement similarity between each of the participants in the space. The music consists of three instruments: a pulsing drone, a clarinet, and an electronic arpeggiation. The drone is constant, but the clarinet and arpeggiation fade in and out depending on the participants' paired similarity. Movement features in the space also determine the rate of the drone’s pulsations, the tuning of the clarinet, the speed of the electronic arpeggiation, and the major or minor tonal center.

The third section is focused more on movement repetition. It has a constant bed of wind-like tones, along with three frequency-modulated oscillators and a percussion groove. The volume of the oscillators, as well as the rate and depth of their modulating low frequency oscillators, is controlled by repetitive movements of the objects. Movement features also control the volume of the percussion. In addition, there is a triggered sound, reminiscent of a video game "power-up" sound, which takes place when the overall group similarity crosses a certain threshold.

To create a more encompassing experience for both participant and observer, three hemispherical speakers (each containing five individual speaker drivers positioned 72 degrees apart, and one driver pointing straight up) are used to broadcast the audio feedback. This allows the audio to sound more dispersed, without any protruding directionality. Please see the diagrams, which are linked in the Audio Examples section, for more detailed information about the audio and gesture mappings.

4. INTERACTION IMPRESSIONS

The design and development of this student-led exploration was an exercise of creating “art as research”, allowing students, professors, and support staff in the School of Arts, Media, and Engineering at Arizona State University to engage in an interdisciplinary collaboration outside of their regular research groups. *Thrii* was first presented at the 2010 Incubator Workshop (February 19-21) held at ASU with the theme: "Beyond the instrument metaphor: new paradigms for interactive media". This workshop brought together leading practitioners in music technology (such as Miller Puckette), human-computer interaction (such as Bill Verplank), multimedia arts (such as Jonah Brucker-Cohen), and cognitive science (such as Marc Leman) to investigate and prototype new directions related to interactivity and interface design for time-based media.

Critical observations by the participants of this first iteration of *Thrii* included simplifying the LED mappings to be more intuitive and connecting sounds to action to be more immediate or meaningful. Positive feedback was given on the simplicity of design, the interesting outcomes of the participants' interactions, and the simple form of the tangible objects. There were participants who immediately engaged with *Thrii* by interacting with the objects and others. Some participants even organized motions among their collaborators to elicit certain reactions from the system. (See THRII_Demo.mov at 00:00:35) [11]

Taking into consideration the feedback from participants who experienced the first iteration of *Thrii*, moderate changes were made to the system, including: modifying the LED mappings by enabling all LEDs to demonstrate similarity, and shortening the time it takes for the audio to react (provide feedback) to similar movements. *Thrii* was then presented for Stephen Wilson, Professor of Conceptual and Information Arts at San Francisco State University and co-editor of Leonardo (the international journal of art and science). He enjoyed the interaction experience of *Thrii*, including the visuals and audio. He recommended catering the transparency of the interaction to specific audiences in different applications, such as: collaborative learning environments among children, versus artistic installation environments.

A group of researchers from Intel Labs, interested in gestural interaction, visited AME and *Thrii* was presented for a third time. The guests first explored the interaction without any guidance, and ultimately interacted with the system in unforeseen ways. The group tried: touching the pyramid projection surface with the spherical objects; placing the objects inside the pyramid; and touching the spherical objects to each other. After their experimentation, they were given a single word to guide them: "Synchrony". The group immediately started moving the objects in a synchronous fashion to elicit engaging feedback from the projection. However, their investigation into tangible interaction between objects and between the pyramid and objects is an interesting aspect that has not yet been considered but may inform future work (i.e., potential utilization of the force feedback built into each Wii remote).

5. DISCUSSION

Thrii includes a number of innovative aspects that make it both an interesting stand-alone installation and provided a foundation for exploring collaborative participation in its future applications. The three-sided pyramid display is one such aspect that promotes group interaction. Because the projections are on a slightly raised surface, participants interacting with the system can hold their gaze relatively level to observe both the activity of the other participants and the system's visual feedback, each of which both exist within the same field of view. An alternative, such as floor projection, would make it difficult to observe both participants and the projection simultaneously. The omni-directional display also allows observers to experience the installation from any angle around the pyramid, which increases the number of people who can effectively view the interaction over an alternative approach, such as wall projection.

An additional innovative aspect of the installation is the visualization of the similarity analysis. The visualization provides insight into one aspect of gesture recognition by illustrating the workings of the underlying algorithms examining movement similarity over time. Such a detailed visualization has the potential of being applied as a learning tool for any algorithm based upon a window of time or a history of data.

In regards to user interaction and user experience, we found that participants were greatly intrigued by the focus on collaborative gestures. We felt that for this initial iteration of the project that a more implicit approach to eliciting similarity in movement would result in the most participant exploration. Initial interactions often focused on individual movements, and prompting often was necessary to realize that the system was reacting to similarity and dissimilarity of movement between participants. After a prompt was given however, participants were almost all self-directed as a group in their exploration and control of the system. Future user studies will provide more information on whether an explicit prompt of new implicit prompt within the system may be used for *Thrii* as an artistic installation and/or educational tool.

Our future plan for *Thrii* is to extend the project into a generalized platform, which can be used to explore many kinds of collaborative models. The underlying analysis algorithm can be applied to any data, such as speech, behavior patterns, or mathematical functions, as long as a similarity measure is provided. One of the potential future venues for *Thrii* is a youth educational conference, for which we plan to expand the system so it allows students to easily modify its behavior for use in learning and instruction.

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6.1 AUDIO REFERENCES

Section 1: http://ame2.asu.edu/projects/thrii/FirstSection.wav

Section 2: http://ame2.asu.edu/projects/thrii/SecondSection.wav

Diagram of Section 2 Mappings:

http://ame2.asu.edu/projects/thrii/Section2AudioMappings.pdf

Section 3: http://ame2.asu.edu/projects/thrii/ThirdSection.wav

Diagram of Section 3 Mappings:

http://ame2.asu.edu/projects/thrii/Section3AudioMappings.pdf