Translation + Pendaphonics = Movement Modulated Media

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ABSTRACT

***Translation* is a multimedia dance performed on a vertical wall filled with the projected image of a lunar surface. Pendaphonics is a low-cost, versatile, and robust motion-sensing hardware-software system integrated with the rigging of *Translation* to detect the dancers' motion and provide real-time control of the virtual moonscape. Replacing remotely triggered manual cues with high-resolution, real-time control by the performers expands the expressive range and ensures synchronization of feedback with the performers' movements. This project is the first application of an ongoing collaboration between the Motivational Environments Research Group at Arizona State University (ASU) and STREB Extreme Action Company.**

Introduction

Translation (aka *Run Up Walls*) is a multimedia performance in which dancers explore movement possibilities availed by the low-gravity environment of the lunar surface. Realizing this experience does not require a mission to the moon. Instead, the dancers ascend a vertical wall with the assistance of custom-designed harnesses and rigging. A video projection fills the wall with a lunar surface that moves and rotates in response to the dancers' movements. A musical soundtrack composed by David Van Tieghem amplifies the atmosphere and augments the sound of the dancers as they walk, run, leap, tumble, and slam into the surface of the wall.

Figure 1. Performers falling face-forward toward the wall after executing a synchronized leap. The projected lunar surface, visible on the wall, zooms in and out based on the performers' distance from the wall. Image captured from video documentation of performance. © 2009 Elizabeth Streb.

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Background

F.A.R. (Future Arts Research at Arizona State University) director Bruce W. Ferguson explains the program's mission:

> F.A.R. has initiated a new model for arts institutions by supporting artists whose "action research" generates new forms of knowledge, using one of our specific areas which resonate with the Phoenix community [1].

F.A.R. sponsored and organized an exploratory visit to connect the STREB Extreme Action Company with the Motivational Environments Research Group at ASU to plan the nature of shows, venues, production logistics, speaking engagements, and community outreach events. A meeting was held in which members of our research group met with performance organization principals and discussed their research agendas. A deep and synergistic excitement emerged from the mutual philosophy of learning by doing, rapidly prototyping solutions, and going beyond what is currently possible, linking science, engineering, art, and human experience with interaction design and dance. Plans soon evolved to form a close collaboration that has extended for the past three years. Discussions of a wide range of sensing technologies and interaction modalities were advanced, iterations of wireless magnetic sensors were explored to trigger sonic events, discussions of more robust motors and bearings for one of the performance company's existing dance apparatuses were had. A rich series of meetings, prototyping sessions, and improvisations, involving dancers, engineers, artists, musicians, and graduate student visits to the STREB Lab for Action Mechanics in Brooklyn, New York, and workshops at an ASU theater ultimately led to the project described herein, which was one of the pieces for the STREB Extreme Action Company's subsequent touring show.

Translation Background

Translation is one of many performances created by Elizabeth Streb's company that explores human movement with physical apparatuses that generate forces and provide obstacles and opportunities for movement that has more in common with circus acrobatics than traditional dance on a flat stage. Dancers performing *Translation* wear harnesses that allow them unrestricted rotational movements while being lifted off the ground. The rigging from the top of the wall to the harnesses places the anchor points at the top of the wall such that when the dancers' bodies are parallel to the floor with their feet on the wall, there is minimal force between the dancers' feet and the wall. In this configuration, the wall becomes the floor for the dancers, with a simulated gravitational force that is proportional to the dancer's distance from the wall (Figures 1 and 2).

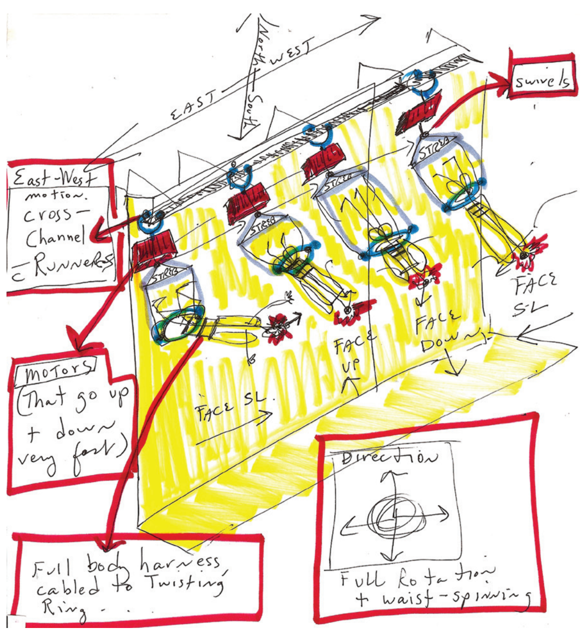

Figure 2. This early conceptual sketch of *Translation* shows the performers in relation to the required hardware that supports this performance. © 2009 Elizabeth Streb.

Pendaphonics Background

Dan Overholt, Anne-Marie Skriver Hansen, Winslow Burleson, and Camilla Nørgaard Jensen invented

Pendaphonics for an interactive art installation in 2008 [2]. Pendaphonics is a combination of hardware and software that allows physical pendulum devices to control audio, video, and other actuators based on the movement of the pendulum bob.

The first performance of Pendaphonics took place at Platform 4 gallery in Ålborg, Denmark, and featured eight Pendaphones (interactive pendulum devices) (Figure 3). Visitors were invited to collaboratively activate the art and performance space, both sonically and visually, by manipulating the pendulums. The natural periods of the pendulums provide rhythmic consistency when they are allowed to swing or orbit freely, but no constraints were placed on the nature of the interactions. Participants could freely move the pendulum bobs by hand, pluck on the string like a bass, or pass it back and forth with their friends. This empowered participants to create a sonic environment that was as ordered and sparse or chaotic and dense as they collectively desired.

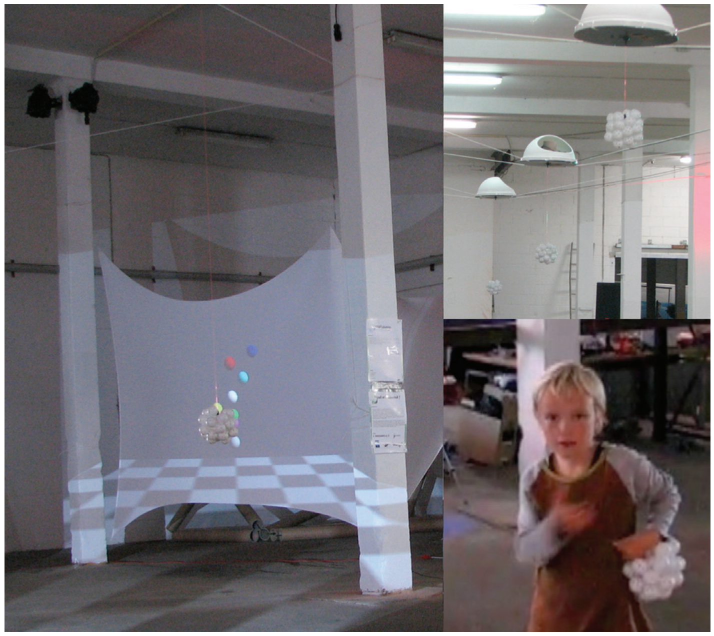

Figure 3. Pendaphonics interactive art installation at the Platform 4 gallery in Ålborg, Denmark. Five Pendaphones are visible; one is being "plucked" by a boy. A video projection shows the positions and movements of all the pendulum bobs. © 2008 Dan Overholt.

Pendaphonics has subsequently been used for research and art installations at numerous institutions, including Ålborg Universitet, Arizona State University, and the University of California, Berkeley [3]. Its uses have included mathematics education, laptop orchestra performances, position tracking for robot navigation, and additional interactive art installations, including one at the New Interfaces for Musical Expression (NIME) conference [4]. Pendaphonics is formally documented in Hansen et al.'s 2009 Tangible and Embedded Interaction paper [5]. Freed et al. provide extensive documentation of artistic applications of the Gametrak, including Pendaphonics [6].

Pendaphonics System

The Pendaphonics system includes modified off-the-shelf hardware and custom software.

Pendaphonics Hardware

The base hardware for the Pendaphonics system is a game controller called the Gametrak [7] (Figure 4). Though no longer in production, the Gametrak remains useful for human-computer interactions beyond the scope of its original design purpose. Gametrak controllers have a simple but very effective mechanism for tracking two points in 3D space. The device uses a small two-axis joystick for each tracked point. As with traditional joysticks, these provide two degrees of freedom (X and Y rotational angles). The third degree of freedom (Z distance) is achieved by sensing the motion of a thin, retractable nylon string that pulls out from the end of the joystick. Electronically, the positions are sensed by the rotation of potentiometers that provide variable voltage to an analog-to-digital converter. The data are formatted by an embedded microcontroller (with a small modification to the board), which provides the data to a computer via USB as a standard human interface device (HID). Depending on the number of devices to be used and their spatial configuration, it is sometimes more efficient to consolidate the output of several Gametrak sensor sets into a third-party microcontroller. In some cases, the original controller packaging works perfectly well, while in other cases, for compactness, specific functional requirements or aesthetics, we have transferred the essential sensing hardware into custom enclosures.

The sensing space for the original Gametrak controller is a cone with a side length of approximately three meters and a total angle of approximately 80 degrees (40 degrees in each direction from perpendicular). For use in the *Translation* performance, this sensing space was not sufficient. The length of the retractable string had to be extended to approximately nine meters. Replacing the original coil spring retraction hardware with another from a modified tape measure, replacing the original potentiometer with a multi-turn potentiometer, and substituting a longer nylon string accomplished this (Figure 5).

Pendaphonics Software

The raw data from the Gametrak controller can be read as a standard HID. The analog-to-digital conversion is 12 bit, providing values for X, Y and Z ranging from 0–4095. We use custom Max [8] software to process these data and translate them into meaningful feedback. This software varies significantly depending on the specific application. For the *Translation* performance, the raw data are received in Max, normalized and filtered, then sent via UDP network connection to a secondary show-control computer running custom Open Frameworks (a C++ toolkit) [9] software to control parameters of the visualization. This software is further explained in the System Architecture section.

Figure 4. The Gametrak video game interface in its unmodified form. The two "joystick" connectors visible on the top of the interface pull out and retract allowing the hardware to provide 3D position information for two tracked points. This interface foreshadowed full body motion interfaces such as the Nintendo Wii, Microsoft Kinect and Playstation Move. © 2009 Byron Lahey.

Figure 5. Extended-range Pendaphone hardware attached above the performance wall. The line from the Pendaphone connects to the rigging used by the performers to ascend the wall. The larger retraction spring in the tape measure replaces the smaller original spring in the Gametrak, allowing the Pendaphone to track 3D motion from floor to ceiling. © 2009 Byron Lahey.

Augmenting *Translation* with Pendaphonics

The previous sections have provided background information on the *Translation* performance and have covered technical and creative aspects of the Pendaphonics system. The following sections will go into more depth on the integration of these two projects.

Motivation and Benefits

For the first generation of *Translation*, the medium was entirely cued and controlled manually, by technicians pressing computer keys. While this system worked, it was not able to fully capitalize on the affordances of the interactive 3D program generating the visual feedback. With manually activated triggers, the system could only produce predefined movements, such as a large or small leap off of the lunar surface. With the Pendaphonics sensor system, the program can provide visualizations, in real time, that correspond directly to the continuous movements of the dancers. The effect of transferring significant parts of the show control from a technician to the dancers did not, and was not intended to, change the choreography of the performance. The performance retains the same movements, scene shifts, and timing, but several key improvements were immediately obvious. The chance of a cue being triggered at the wrong time, while rare with manual control, was essentially eliminated. The high-resolution position sensing allowed the magnitude of the dancers' movements to be matched with perfectly scaled movements of the projected ground under their bodies. The sensor control allowed the show technician to focus on other aspects of the presentation.

Pendaphonics Versus Alternative Motion Capture Technology

The team working at the STREB Lab for Action Mechanics (SLAM) had long considered the benefits of integrating motion sensing with their multimedia dance performances. Surfaces are often outfitted with microphones to amplify the acoustics of the bodies that impact them. Elizabeth Streb has compared the use of physical apparatuses for expanding the range of human movement with the use of musical instruments to augment the human voice [10, 11]. Technology, especially in the form of mechanical inventions, is integral to the vision of this performance group. The reason for not including motion sensing has not been ideological. It has been purely practical. Optical motion capture was not considered viable for several reasons. The complex visual environments that include performance apparatuses, video projections, and the presence of audiences and support technicians in unpredictable locations make the occlusion of tracking markers extremely likely. Physical markers would create pressure points incompatible with the nature of the actions of the dancers and would be difficult or impossible to keep in place. Calibration requirements would be too time-consuming for live and traveling performances. Markerless optical systems are even more sensitive to environmental variables. Beyond these technical obstacles, full-blown motion capture systems optimized for special effects production and research activities provide much more data than what is required for this application.

While a comprehensive survey of alternative human interfaces and motion tracking systems is beyond the scope of this paper, a few interesting, related alternatives should be noted. Kaufman presents a mechanically linked, harness-based motion capture system targeted at military virtual reality training applications [12]. This system would not match the low encumbrance requirements for the STREB performers. Yang and Pai discuss the use of a harness outfitted with load cells [13]. In their research, the application automatically detects slips for use in movement therapy. While this is a significantly different application area, the availability of force sensing in the performers' harnesses could expand the creative potential of our system. Char Davies' *Osmose* [14] used a Polhemus Fastrak [15] sensor to measure position and orientation, and a custom vest/harness to measure the expansion and contraction of the wearer's chest. The Polhemus system costs around $6,000, so while this sensor could technically be a viable alternative, it would be much more expensive. The approach used to sense breathing in *Osmose* is an interesting one to consider for future collaborations with STREB, but it would require carefully designed wearable hardware for the extreme demands of the performers.

The Pendaphonics system was a natural fit for this particular performance, as the dancers are suspended in harnesses (see Figure 6) and effectively become pendulums. The Pendaphone hardware allowed us to track the dancers' movements in three dimensions as they traveled up and down the wall. The Pendaphone hardware, being based on a commercial game interface, is designed to be simple, low cost and very robust. Since the sensing is mechanical, visual occlusions and complexity are not relevant, and radio-frequency interference is never an issue. Pendaphonics has no encumbering effects on the dancers, enhances the expressiveness of the visual feedback system, and reduces the workload of the show technicians during live performances.

System Architecture

The integrated *Translation* and Pendaphonics system includes:

- 25-foot-tall vertical wall
- Custom harnesses that allow rotation on the torso axis
- Swivel connectors allowing rotation on the support cable axis
- Steel cable rigging line from the harness to the anchor point
- Electric motor winches to lift and lower dancers
- Pendaphonics hardware with line connected to rigging cable

Figure 6. Custom harnesses that allow for free rotation about the torso and rigging line axes. These harnesses, similar to those used for special effects stunt-work, allow the performers to flip, twist, and move freely across the wall. © 2009 Elizabeth Streb. Photo © 2009 Byron Lahey.

- Laptop computer running Max Pendaphonics software
- Main show-control computer running Open Frameworks *Translation* visualization software
- Ethernet cable connecting Pendaphonics computer and show-control computer
- Audio-cue computer and PA system
- Video projector
- Three performers
- Technical support staff to supervise and run computers and motors, and assist performers

Aaron Henderson programmed the visualization of the lunar surface using the Open Frameworks C++ toolkit. This visualization has a spherical object mapped with an image of the moon's surface. This sphere can be rotated in any direction at any speed and can be oriented to and positioned at any distance from the virtual camera. This control allows the performers to walk on the real floor towards the wall with an image of the moon very low on the horizon. As the performers transition from standing on the floor to walking up the wall, the virtual moonscape gradually shifts to a top-down view, so it appears that the dancers are walking on the surface of the moon and are being seen from overhead. When the dancers leap off the wall, the virtual distance to the moon is increased. This virtual distance is increased in an exaggerated scale, giving the optical impression of extremely large leaps. As the performers move toward one side of the wall, the moonscape rotates under their feet (as a treadmill would). Exaggerated rotational speeds are used expressively to give the illusion of very fast motion. Control of these visualization parameters is split between manually triggered cues and real-time Pendaphonics-driven modulation. Manual cues are used for major scene transitions (for example, when the performers transition to and from the wall) and when real-time sensing is potentially incongruous with the desired feedback for a particular section. Real-time Pendaphonics control can be manually overridden in such cases.

Project Outcome

"The idea of taking mechanization, and taking robotics, and taking machines, and mixing them with human movement potential, and space and time, is really what the whole category of investigation is about" [16]. Elizabeth Streb states: "I think that people ignore and don't perceptually notice movement" [17]. Streb describes the importance of having microphones positioned everywhere to allow the audience to hear the impacts of bodies against floors, walls, and performance apparatuses. The idea is to convey the substantiality of these impacts to the audience. The Pendaphonics system serves the same conceptual function as the microphones: amplifying a signal (in this case motion) to make it more perceptible to a large audience viewing the performers' movements at a distance. Streb suggests that this amplified movement induces a feeling of vertigo in the audience. Streb, the production staff of Streb Extreme Action Company, and the Pendaphonics creators viewed the integration of the Pendaphonics system with the *Translation* performance as a great success. With this system, the dancers had direct control of key visual feedback parameters. This transfer of control improved the expressive range of the feedback by providing real-time position control of the virtual height and rotation of the lunar surface.

This project served as a proof of concept of the effectiveness of using low-cost sensors and custom software to sense the motion of dancers and performance apparatuses in a challenging environment. This sensing can enhance control of existing feedback and allow for the creation of new data-driven media that can reveal additional forces and actions, expanding the creative palette of the artistic director.

For this iteration of the project, a single Pendaphonics sensor connected to a single performer was used as a simple resolution to the problem of potentially conflicting data when, for example, one performer made a big leap while the other two remained close to the wall. For future iterations, all the performers' positions will be monitored and a more sophisticated algorithm will be generated to selectively average, filter, and prioritize sensor data for particular segments of the performance.

Opportunities

While working on the integration of Pendaphonics with *Translation*, we experimented with using Nintendo Wii Remotes [18] to measure the acceleration of spring boots worn in another performance. The wireless data from this type of sensor could enhance the perceptual experience of this performance by revealing the forces involved. Of particular interest might be the moments of zero gravity at the apex of leaps or the distinct data patterns created when the performers do flips. Feedback from these data could be in the form of audio, projection of light, or any other computer-controlled form. The application of real-time sensing need not be limited to audio and visual feedback. Physical actuation of performance apparatuses based on real-time sensing would open up new movement experiences and choreographic opportunities.

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