AUDIO ORIENTEERING – Navigating an Invisible Terrain

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Abstract

AUDIO ORIENTEERING is a collaborative performance environment in which physical tokens are used to navigate an invisible sonic landscape. In this paper, I describe the hardware and software used to implement an audio terrain with multiple interaction modes and sonic behaviors mapped onto approximately one cubic meter of space. After this successful proof-of-concept, I identify several methods that will extend the system's responsiveness, range, and accuracy.

Keywords: wii, 3-d positioning, audio terrain, collaborative performance.

1. Introduction

This piece allows multiple users to explore an invisible landscape using orientable physical tokens. Each user will hold a wooden "Egg" containing sensors that track position and orientation. The Egg's position is superimposed onto a pre-composed "terrain" of sound, revealing and concealing various sonic "landmarks" as users move through the space. The multiple-user model allows for many modulations with relatively few landmarks. An Egg's orientation will manipulate sonic parameters local to each waypoint, so that while actions are repeatable, they are not consistent across the space—for example, the same gesture may have different results depending on the user's position within the space.

2. Background

My practice explores the modalities and metaphors surrounding the relationship of a body-in-space to an audio source. Here, my interest lies in placing a group in a context that causes them to think carefully about their relationship in/to space, and how to modulate that relationship. These explorations are rewarded with a compelling and richly responsive audio output.

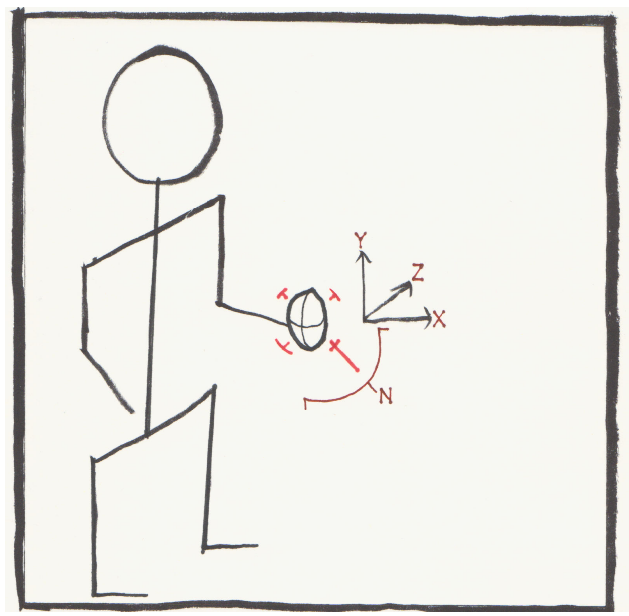

Figure 1. Conceptual model of Egg

A compass is an object that transforms an invisible phenomenon into information about one's immediate physical environment. It is a point of intersection between the virtual, conceptual space of geomagnetism and the physically-perceivable world.

In AUDIO ORIENTEERING, I have abstracted the symbolic function of a compass and inverted the physical/virtual relationship. Here, each Egg (see conceptual diagram, Figure 1) functions not only as a token whose position in the room maps isomorphically onto another, invisible space, but also as a point of inflection around which these real and imaginary spaces may pivot. Here the metaphor of an audio terrain becomes useful—whereas a song is a one-dimensional progression from beginning to end, AUDIO ORIENTEERING presents a multidimensional map of sonic elements on which its users are free to improvise and explore.

While not an instrument in and of itself, this interface is a new mode of interaction between a participant and the space's music, complicating the relationship between composition and remix: each user's trajectory through the space endlessly reconfigures a complete-but-asynchronous original composition.

3. Implementation

AUDIO ORIENTEERING uses one MacBook Pro running Processing 0135 and Ableton Live 7. This computer receives orientation data from each Egg using the Zigbee stack, a low-cost, high-bandwidth mesh networking wireless protocol developed over the last two years. Three-dimensional position data is captured by two Wii remotes (called "Wiimotes"), inexpensive Bluetooth controllers manufactured by Nintendo which contain IR cameras and built-in blob detection hardware. To improve object-tracking ability on the Wiimotes, each was outfitted with a custom ring light of infrared LEDs.

In this iteration of the AUDIO ORIENTEERING project, certain secondary features have not been implemented. I will discuss these compromises and features to be introduced in future iterations in Section 5.

3.1 Hardware

For this implementation, hardware for the Egg was mounted onto an acrylic form to facilitate debugging. Each Egg (see Figure 2) has a small sphere covered in retro-reflective tape that serves as the main tracking point for the Wiimotes as described in Section 3.4. In addition to the reflective tape, each Egg contains an inexpensive 2-axis accelerometer and a XBee wireless board.

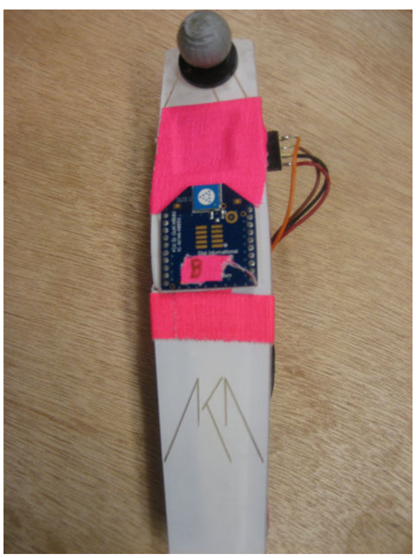

Figure 2. The "Egg" wireless device

3.2 Software

All the object tracking and MIDI mapping is done in Processing, which I chose for its ease of use, free availability, and large community of artists and engineers. To get information from each Wiimote, I used open-source libraries available on the Wii hacking website wiili.org [1], as well as on the Processing community forums. In particular, I used RWMidi [2]; wrjp45 [3]; and wiiremotej by [4]. By integrating these libraries' functionalities, I was able quickly to experiment with arbitrary space-to-MIDI mappings in relatively few lines of code.

3.3 Dead Reckoning

Initially, I tried to determine each Egg's position using dead reckoning, also known as inertial navigation. This approach was attractive in part because it is unaffected by the local characteristics of the space such as occlusions or ambient light. One of the goals of my work is to make the system easy to deploy anywhere, so inertial positioning or other self-contained absolute positioning methods are clearly the most desirable.

Despite substantial improvements in accuracy and filtering of accelerometer and compass data, such methods are still not precise enough to determine absolute position without some form of external reference. I implemented a simplified Kalman filter in order to provide some rudimentary correction, but results were not significantly improved.

3.4 Optical Positioning

In order to continue work on the project, I augmented each Egg with an external-reference system similar to those used by professional motion-capture suites such as Vicon [5]. In particular, I chose to adapt the consumer-level "DIY" approach first popularized by Johnny Chung Lee [6].

In my approach, one Wiimote's IR camera looks head-on at the performance space and provides x- and y-axis data. A second Wiimote, roughly orthogonal to the first, provides a rough z-axis position. Future implementations of this work will involve a more thorough trigonometric calibration of absolute position using a method inspired by Hay, Newman, and Harle at Cambridge [7].

I decided to set up the IR cameras so that the bottom of the field of view coincided with the floor. This orientation reinforced the physicality of the invisible space to be explored by providing a literal and figurative "grounding" common to both spaces. One additional benefit to this arrangement was that users ended up kneeling and/or sitting in order to better explore the virtual space, which in this implementation was about a cubic meter in size.

3.5 Mappings

In order to present a complex and engaging experience, several different position-to-control and orientation-to-control mappings were implemented simultaneously:

3.5.1 Spheres of Influence

Using simple distance-based calculations combined with proportional relationships familiar to everyone (for example, the inverse square law), single points in space can be perceived through the proportional increase or decrease of the volume of a particular sonic element or loop. Once inside this sphere of influence, the Egg's orientation (pitch and roll) became mapped to other qualitative changes in the same sonic element—for example, once inside the sphere of influence of a looped vibraphone sample, the pitch of the Egg modulates the cutoff of a lowpass filter, and the roll modulates a downsampling effect.

3.5.2 Contours

Similar to contours in a topological diagram (see Figure 3), the contour mapping is a series of irregular shapes split up by their altitudes. X/Y position within the bounded space alters sonic characteristics in one way, while ascending or descending to another contour level will alter another set of parameters.

3.5.3 Multi-user metaparameters

In addition to mappings based on individual position information, other sonic parameters are linked to aggregate data gathered from all the Eggs in play. For example, when Eggs are all pointing in a certain direction, different modulations and sequences will be played than if they were not aligned. The intent in this form of mapping is to encourage users to be aware of each others' movements and positions, and to encourage group play and exploration.

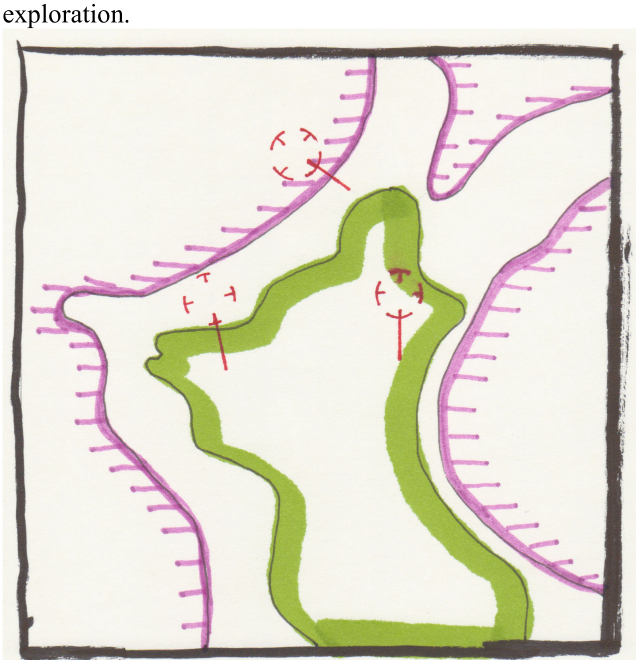

Figure 3. A contour terrain with three Eggs

4. Results

Users were able reliably to locate and return to different places within the virtual terrain. The most common errors observed were due either to occlusion of the beacon or to software errors in binding incoming accelerometer data with the correct IR beacon.

Users reported a satisfying experience limited mostly by the small range of the current camera and illumination setup. Most mappings were readily understandable, although in different areas of the space more or less overlap of features was desired—for example, at one point in the space, position information was doubly mapped, affecting both a bassline and a vibraphone instrument. Users felt that the space would benefit from either an Egg-based method of selecting which parameters would take precedence, or a simple form of tactile or visual feedback to indicate entrance into a complex or multiply-mapped area. Such additions are addressed in the following section.

5. Limitations and Future Work

The possibility of occlusions and relatively small working area are the main areas in which this approach needs improvement. Range can be improved significantly by increasing the size and power of the IR ring lights, and more Wiimotes can be added to the setup in order to minimize occlusions. However, adding more camera devices will diminish the portability and versatility of the setup.

In order to maximize the flexibility of this system, I will work towards removing all cameras from the setup and using an internal inertial measurement unit (IMU) with Global Positioning System (GPS) for external positioning. With the addition of a GPS module, user scenarios can include the traversing of entire geographical areas, effectively allowing one to "sound design" an entire neighborhood. In such an application, audio generation would have to be handled in a manner local to each Egg, but this opens many new and interesting doors (for example, the ability to exchange samples or mappings over a Personal Area Network (PAN), or even to collaborate with other explorers in the area).

I would like to incorporate several forms of haptic and visual feedback into each Egg. A ring of lights just below the surface of the wood could act as a compass that only becomes visible at points of crisis/opportunity—for example, when three of four Eggs are pointing in the same direction, the fourth Egg could begin to show where it should be pointed in order to line up with the others. Simple but invisible data, such as the average "shakiness" of each Egg, or the average orientation of all Eggs, could easily be communicated in this manner.

Another interesting form of feedback is a vibrating motor—this would allow users to "feel" their way around an invisible space by vibrating when the Egg is brought to a boundary point between two sonic regions. At present, I am designing these capabilities into the system but not yet incorporating them until I can be sure each Egg will have sufficient battery life and an acceptable form factor.

One final step to take in making this system available to anyone is the creation of software that streamlines the composition process by easily visualizing and recording the different modes of dimensional interaction described in Section 3.5. This could take the form of an add-on for freely-available 3-d software like Google's SketchUp or even Google Maps, or it could be a simple Egg-based entry system using additional "record" and "assign" buttons placed on the Eggs themselves.

6. Final Words

Using off-the-shelf consumer electronics, free or low-cost software, and the help of a dedicated online community of hardware hackers, I have demonstrated the feasibility of three-dimensional, multi-user audio terrains that can be easily transported and enjoyed with little or no setup time.

7. Acknowledgments

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