AtmoSPHERE: Representing Space and Movement Using Sand Traces in an Interactive Zen Garden

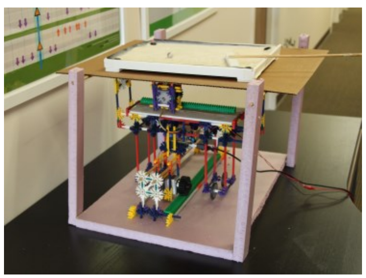

Figure 1. AtmoSPHERE is an interactive Zen garden that tracks human movement using a Microsoft Kinect and simple computer vision algorithms and represents this movement via unique, tranquil sand trace visualizations. See supplementary video: http://goo.gl/MjHcfi.

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Abstract
A Zen garden, also known as Japanese rock garden or Ryoanji garden [1], creates a peaceful way to visualize space and tranquility. In this paper, we introduce *AtmoSPHERE*, a new method for automatically imbuing a Zen garden with properties of its surrounding space and occupants. AtmoSPHERE uses a Microsoft Kinect to monitor and extract movement in a room and then visualizes representations of this movement *physically* via sand traces on a custom built XY sandbox table. We present our prototype system, the design process and interaction modes, feedback from a preliminary deployment, and a discussion of future work.

Author Keywords
Visualization; Tangible Interactive Art; Machine Aesthetics; Calm Technology; XY Servo Table; Kinect

ACM Classification Keywords
H.5.2. Information interfaces and presentation (*e.g.,* HCI): User Interfaces. I.4.9. Image processing and computer vision: Applications.

Introduction
The tranquility of space plays a significant role in our daily life. We are exploring new methods to create "calm spaces"—to enhance a space's sense of tranquility—via interactive art installations that adapt to

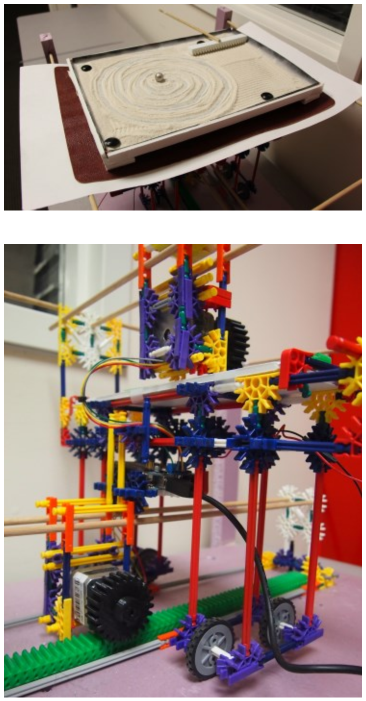

Figure 2. The AtmoSPHERE prototype system consists of four pairs of 3D printed gears and tracks, two stepper motors, one super magnet marble inside a sand box, and a Kinect that can detect the room occupants' noise levels as well as track their movement.

a space's environmental conditions and/or the occupants within it. For this project in particular, we were inspired by Zen gardens, also known as Japanese rock gardens or Ryoanji gardens, which consist of rocks placed on raked gravel to create peaceful feelings for meditation [1]. Classical Zen gardens are static stylized landscapes. People usually admire Zen gardens while seated from a single point of view to appreciate the aesthetic appearance and to meditate.

As exploratory work, we wondered: could we create a Zen garden that monitors its surrounding space and automatically responds to the people within that space? Could we create physical visualization to reflect the noise level within that space? To answer these questions, we design and implement AtmoSPHERE (Figures 1 and 2), an interactive Zen garden that creates unique sand traces representing human movement and ambient sound levels in the installed space. AtmoSPHERE uses a Microsoft Kinect and simple computer vision algorithms to extract human movement traces and a custom built XY stepper motor table (XY table) along with a magnetically controlled marble to create physical "sand trace" visualizations. In this paper, we describe how we built the system, its interaction modes for visualizing movement and sound, as well as feedback from a preliminary deployment. Please see our supplementary video for a demonstration: http://goo.gl/MjHcfi.

Related Work

We describe related work in visualization and detection techniques of room occupants, XY tables, machine arts, sand arts and Zen gardens.

Visualization of space occupants

Past work has focused on visualizing room occupants in digital 2D or 3D forms. For example, Kuutti *et al.* [7] use basic dots and arrows to render current building occupancy. Rassia [8] constructs a flow map and superimposes it over a floor plan to visualize occupants' activity for a typical workday. Chao *et al.* [10] creates interactive Bézier curves and heat map to visualize consumers' footpath in a mall. Breslav *et al.* [6] design 3D animations with glowing effects to visualize occupant movements and created a 2D clock widget interface to consolidate time-related events. In contrast, our work creates physical visualizations of occupant movements using sand traces to create a novel, interactive Zen garden experience.

Detection of space occupants

There are two main sensing approaches to track occupant movement: infrastructure-based mounted in the environment and on-body sensors. For instance, Kuutti *et al.* [7] utilize a network with 15 sensor spots including direction sensitive light beams and infrared (IR) camera sensors to detect the room occupancy levels in a factory building. In contrast, Rassia [8] uses location-tracking devices that transmit a unique ultra-sonic signal every 10 seconds to track 56 users in AT&T laboratory.

As for occupants in smaller spaces, cheaper solutions such as using an RGB camera and Kinect been proposed. Early in 2005, Dalal *et al.* [3] utilized Support Vector Machines (SVM) with Histograms of Oriented Gradient (HOG) features to detect humans from RGB images. In 2011, Xia *et al.* [4] used depth information from the Kinect to detect humans by combining 2D head contour models and a 3D head

Figure 3a. Spiral painting pattern from Metaphone [5] using bio-data.

Figure 3b. Spiral sand traces from AtmoSPHERE using number of occupants and tranquility level.

surface model. Recently, Kinect's built-in skeleton detection algorithm has been widely applied in indoor scenarios. In our work, we use the Kinect to track occupant movement.

XY Table

The XY table, which was first patented in 1967 by Alfsen Christian [9], is widely used in devices such as scanners, 3D printers and cutting machines. With accurate movement along X and Y axes separately, XY tables provide precision-controlled movement to any point within a rectangle region. Our inspiration for developing a rapid prototype comes from [12-13]. While they use raw materials cut by a CNC machine, we use quick-to-assemble pieces from a K'NEX kit (K'NEX is similar to Legos). Our drawing mechanism, which moves a metallic marble in a sandbox, is similar to dePENd [2], which moves the metal tip of a pen to assist sketching.

Machine Arts

Simbelis *et al*. [5] generate their art through an experimental machine, *Metaphone,* which creates a process of movement, painting and sound with users' biometric data: Galvanic Skin response (GSR) and Heart Rate (HR). As reported by 6 participants, *Metaphone* induces a relaxing atmosphere. Inspired by Figure 3a from [5] as well as Zen gardens, our prototype creates aesthetic patterns similar to *Metaphone* on the sand based on the occupancy and ambient sound level of the installed space.

Sand Arts and Zen Gardens

Sand arts can be a fascinating form to express creativity. In *Lazy Man Zen* garden project [14], artists designed a drawing machine that operates a ball with four cables to create sand art. Recently, Disney Research published *Beachbot*, which can create large scale sand art using an autonomous robot [15]. Whereas drawing patterns in these works are pre-defined, AtmoSPHERE introduces interactivity between humans and sand arts. The metallic marble located in the sandbox mimics the walking of occupants inside the "garden", providing a peaceful aesthetic imprint of the co-habitants movement in the space.

Design Process

We built the proof-of-concept prototype called AtmoSPHERE to demonstrate the feasibility and aesthetic perspective of our concepts. The prototype is built with the following hardware and materials:

- Microsoft Kinect for Windows
- Arduino Uno with Adafruit Motor Shield
- K'NEX toys
- 2x 12V 200 step/rev stepper motors
- 2x 3D printed gears and tracks
- 2x Super magnets (4lb force neodymium)
- 2x DC stepper motors (200 Newton radial torque)
- Composite foam, 1/4" oak dowel rods
- Sand, cardboard, glue, tape.

The driving notion behind constructing this prototype was the visualization of movement in space. To accomplish this, we wanted to be precise, thus our development of a custom XY table. We also wanted an artistic and unobtrusive drawing method, so we designed the magnetically controlled marble. The XY table is constructed with stepper motors moving along

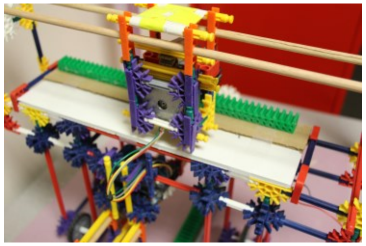

Figure 4a. The stepper motors are mounted by K'NEX toys with iterative fast prototyping.

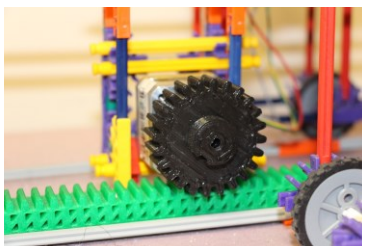

Figure 4b. 3D printing is used for designing gears and tracks so that the stepper motors can precisely move magnet in XY table. Our gear and gear track is remixed from diofantico's design on Thingiverse [11]

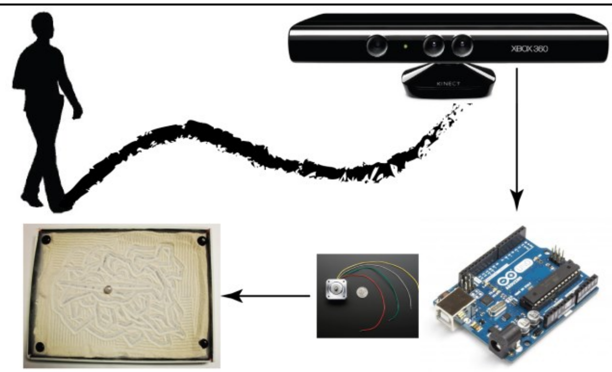

Figure 5. Workflow of the tracking mode.

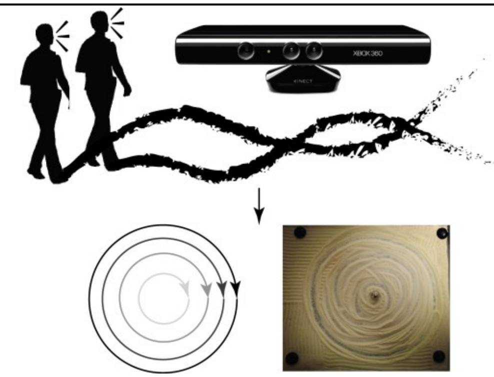

Figure 6. Workflow of the spiral mode.

the X and Y axes on two different levels. To reduce friction and allow for smooth movement, we hang the motor along a wooden rod and use 3D printed gears and tracks supported by wheels.

Prototyping with K'NEX and 3D printing

K'NEX, creative construction toys played a crucial role in our design process. One of the advantages of using children's construction toys is that they can help you iterate through many different prototypes quickly to see what works. We use numerous K'NEX toys to construct the carriages for stepper motors, gears and magnets. As illustrated in Figure 4a, the main components of the K'NEX carriage are the wheel support and motor mount.

However, K'NEX toys could not be used to construct a precise coordinate system. Thus, we also used 3D printing extensively in our iterative prototyping. To establish an XY table with stepper motors, we 3D printed gears and tracks so that each motor could move along one straight line (Figure 4b). Afterwards, we built two height levels of motors, gears, and tracks — one for each axis. In this way, we construct a low-cost XY table with motors, K'NEX, and 3D printed gears and tracks.

Visualization: Zen Garden in a Sand Box

The physical sand visualization sits above the K'NEX and foam structures. We fill an extremely thin (~1/8 - 1/4in thick) layer of sand in a paper box (15.6 x 11.7in) and place a spherical neodymium magnetic marble onto the sand. The other magnet is attached with the upper-level motor. So as long as the XY table points to a target position, the top magnet would move together, leaving the aesthetic trail on the sand as a form of physical visualization.

Occupancy and Tranquility Detection by Kinect

We use a Kinect for Windows to detect the occupancy and ambient sound level of the surrounding space. To ensure the maximal field of view for the Kinect, it is positioned in a high place. We then configure the

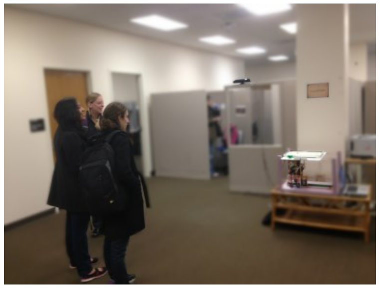

Figure 5. AtmoSPHERE was deployed in an open space within our lab HCIL. Students, colleagues and passers-by provided initial feedback for us.

response time of recorded sensor readings in relation to actual motor movement. Due to the speed limitation of the motor, we limit the occupancy and sound data to be sent every 500 milliseconds.

Tracking mode

Our initial approach for creating a visualization was to render human movement directly onto the sand. First, we used one person to walk around the space in order to calibrate the Kinect's field of view (FOV). Then we established a one-to-one mapping from the walking space to our Zen garden in the sand box. Since the XY table only supports a single marble moving at a time, we treated the person *closest* to the central point of Kinect's view as the "principal" occupant. The entire workflow of tracking is illustrated in Figure 5:

- The Kinect detects and tracks all occupants' movement within the space. The *"principal"* occupant's position is sent to the Arduino every 500 milliseconds.
- Arduino updates the target position and decides the next step (rotation speed) for both motors.
- The marble attached to the upper-level motor moves according to the *"principal"* occupant's trace. The trace is thus physically visualized on the sand.

With this tracking mode, we are unable to visualize multiple people in the space. This led us to the design of a spiral mode to visualize the level of occupancy as well as tranquility.

Spiral mode

In spiral mode (Figure 6), the Kinect detects the number of occupants within the space as well as the noise level, which is processed by a laptop and sent to the Arduino for driving the motors. The neodymium marble renders a circle with a radius proportional to the number of occupants in the room. The speed of the marble corresponds to the amplitude of the ambient sound. The more occupants within the space, the larger the radius is drawn; the noisier, the faster the sphere moves on the XY table.

Preliminary Deployment

To get initial feedback on our prototype, we deployed the system in an open space within our lab (the HCIL) and gathered feedback from 18 graduate students and passers-by (See Fig. 5). In general, reactions were positive. Most people appreciated how their movements were visualized in the "Zen garden" in the sand. Some users especially liked how the marble "followed" their pace and left an aesthetic trace in the sand.

We also received some criticisms and suggestions for future work. One of the major concerns was: with long-time deployment, the current prototype cannot display the traces in the past since a new trace would overlay the old ones (though this ephemerality was part of our design). Some people also mention that it was hard to understand the spiral visualization at first glance.

Conclusion and Future Work

In this paper, we described a prototype system that visualizes the space and tranquility in an interactive, Zen garden using sand traces. We received initial feedback from occupants in a preliminarily deployment.

We have two directions for future work. One is to create temporal visualization in a much larger XY table. The sand box would be divided into twelve portions, with each portion representing one or two hours in the day. The marble would visualize as it did in either tracking or spiral mode. It would move to one of the 12 quadrants based on the hour. This would give users a temporal visualization of the entire space over a 12-hour time period. The other direction is to use multiple marbles representing multiple occupants, indicating more random rocks on the raked gravel in real Zen gardens. The magnetic marble could be programmatically attached or detached from the motor. In this way, more aesthetic drawings might be generated and a more abstract translation of the atmosphere could be displayed in the physical visualization. In the long run, industrial-level materials could replace the K'NEX toy infrastructure for future deployment and improve the motors' average respond time.

Finally, to help others create their own interactive Zen gardens, we have posted a step-by-step tutorial on Instructables.com (http://goo.gl/WJOhCQ). We also intend to conduct a long-term case study to see how users would like to interact with the visualization and the impact it can have on their daily life.

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