Tilting Table:
- A Movable Screen -

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ABSTRACT
In screen-based experiences, the screen itself can become the physical device used for interaction. The "move-ability" of the screen affords interactivity between the screen artifact and the viewer, and between the virtual and physical spaces. We have created a movable screen interface, called the *tilting table*, which provides a display surface via overhead projection. This interface invites user interaction through the action of tilting the tabletop. The degree of tilt affects the displayed visuals and audio output. This simple interaction makes users feel they have a closer connection to the virtual imagery, and the screen thus blurs the boundary between them. In this paper, we introduce four applications that have been implemented for the tilting table. Two use an artistic approach to create expressive and entertaining media interactions, while two have been developed for navigating large information spaces. Each application is described and user feedback is discussed.

Author Keywords
Tangible interface, tilting table, interactive video and sound installation, navigable information space.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces---input devices and strategies, interaction styles; H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces---collaborative computing, synchronous interaction.

INTRODUCTION
The screen exists in the boundary between real-world spaces where viewers are located and the virtual world of images. Traditionally, in screens of interactive media (computer screens or sometimes TV screens), mice, keyboards, or remote-controllers are the tools with which users navigate or interact with the worlds inside the screen [2, 8]. However, sometimes the screen itself can be the very device for interaction or connection between these two worlds, e.g. a touch screen. In that case, the screen functions as display and interface simultaneously. The movable screen is another idea for the screen as an interface and a display. However, compared to touch screen interfaces, the movable screen can provide a stronger sense of tangibility. It affords greater free body movement, which can enhance the sense of seeing and touching. This may allow more familiar, social, and playful interactions from the viewers.

The tilting table closely ties a viewer's movement in physical space with virtual displayed images to encourage a tighter bond between the real and the imagined. One of our key design goals is to create experiences that, in terms of both their interaction and content, can commingle or blur the boundary between the viewer and the image. Through our research to date, we have found that this simple platform opens up a wide variety of application possibilities. This paper discusses current applications for the tilting table and early user feedback.

RELATED WORK
These have been past works that provide interaction experiences based upon changes in the tilt angle or position of screens. In the show entitled "Experiments in the Future of Reading," in the Tech Museum of Innovation in San Jose, California, Onomy Labs exhibited a "Tilty Table" [1]. This table displays an interactive book where tilting the table controls page scrolling. Onomy Labs also recently developed a *Geo-Explorer Table*, which deployed an interactive map on the Tilty Table, much like our Tiltable Maps application described later in this paper.

Oakley and O'Modhrain, from the Palpable Machines Research Group at MediaLabEurope, have developed a technique of using the orientation of a device for navigating through one dimensional lists or menus, with a focus on mobile handheld devices [4]. Their novel input mapping combines changes in orientation with vibrotactile feedback, positively affecting user performance and experience in navigating information on small displays. Another related

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project is the Ballancer interface, which uses a tilting bar to control the sound of a virtual rolling ball [6]. Other examples of tilt interfaces include scrolling a two-dimensional canvas such as a map [7] and navigating through one-dimensional menus or lists [5].

TECHNICAL IMPLEMENTATION

Our tilting table uses an accelerometer (a sensor for measuring gravity) for detecting the movement of the tabletop in response to user actions. The accelerometer communicates the tilt-angle values to a PIC micro-controller, which then delivers those values to a computer via either MIDI or serial communication. Computer-driven real-time images are transformed by the input and displayed on the tilting table surface by a ceiling-mounted projector (Figure 1).

Mechanically, the joint for the tabletop has been implemented in two ways. Our first version uses a ball-joint, while the second uses a spring. These two joints have different traits: with the ball-joint, the tabletop remains in the last position in which the user left it; the spring, because of its resiliency, returns the tabletop screen to its original position after the user's interaction.

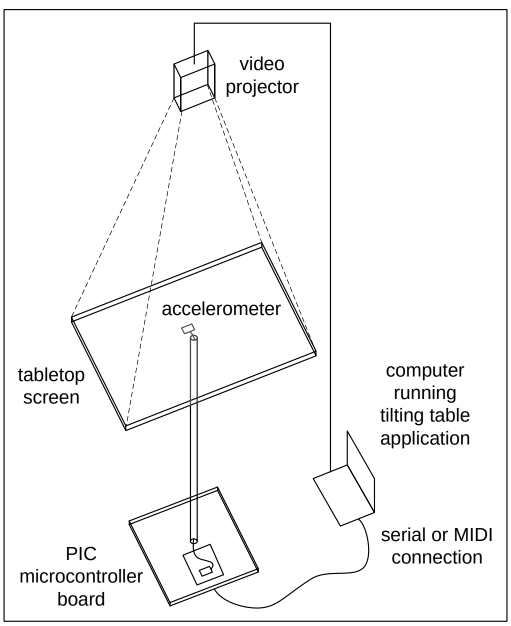

Figure 1. Tilting table setup.

USER INTERACTION

In the current version of tilting table interface, interaction involves manipulating of the angle of tilt by grasping the edges of the table. When the tabletop is tilted slightly, the accelerometer registers a lower gravity, and a larger degree will register a higher gravity.

The choice of using a ball or a spring affords different kinds of responses from the table surface, supporting different interaction styles and applications. For example, since the ball-mounted table remains at the last position directed by the user, so too could the content. Or perhaps the content could continue to move in the same direction. In contrast, since the spring-mounted top returns to its original position, it might bring the user back to the starting point within the content space as well.

APPLICATIONS

To date, we have implemented four different applications on our tilting table interface. The first two provide an artistic approach for expressive and entertaining displays. The following two are interfaces for navigating content, places, and spaces.

Interactive Arts

We describe here two interactive video and sound installations that have been implemented on the tilting table. These two pieces, titled *A BeadBall Table* and *Cross-Being: Todd* are both designed for display in art galleries or museums.

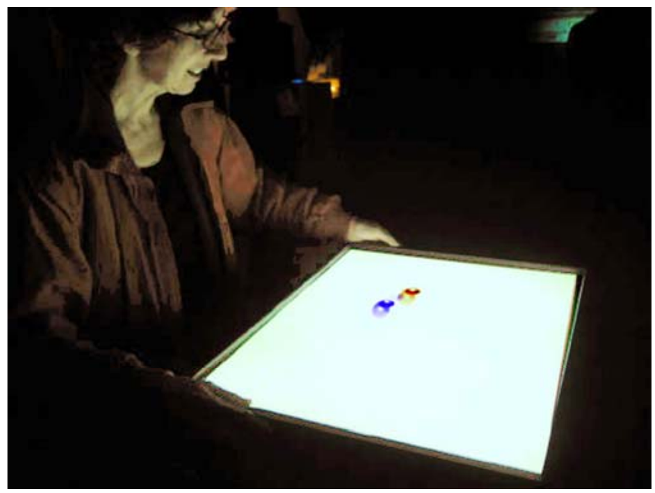

Figure 2. Users roll virtual beads by tilting the table.

A BeadBall Table

Virtual beads are projected onto the surface of the tilting table. As viewers tilt the tabletop, the beads roll towards its lowest corner. The direction and angle of tilt also generate sounds which provide musical accompaniment for the rolling beads. A Max/Jitter patch was created to manipulate the video and sound in real-time based on the sensor input.

In this work, real world physics (gravity) is applied to the relationship between the balls and the tabletop, producing a witty parallel between the real and virtual, and providing viewers with a fun, playful, and sometimes surprising interaction. This piece was exhibited in a 2004 show at NYU's ITP, during which we were able to get feedback from a large number of visitors. Many of them suggested that this application could be implemented as a game, perhaps in which players try to roll the beads into a virtual hole or around a maze displayed on the table. In this case, users would have a specific goal to accomplish in their interaction.

Cross-Being: Todd

The background concept and methodology of this piece is similar to *A BeadBall Table* described above. But in this case, if the user tilts the tabletop, Todd, a virtual being that exists on the screen, slides towards the down-leaning corner of table, as shown in Figure 3. The noticeable difference between these two works is the characteristics of the virtual existence inside the screen. In *A BeadBall Table*, the ball is a passive object with a simple round shape. In *Cross-Being: Todd*, the virtual character becomes a more complicated entity, embodying human-like behaviors and emotional expressions in his actions on the screen. For example, if nobody touches the table, Todd gets bored and sits down at the center of the screen. If users disturb him for too long, Todd gets angry. Because of Todd's changing behavior, we needed to provide a more flexible and articulated content structure than was needed for the virtual beads.

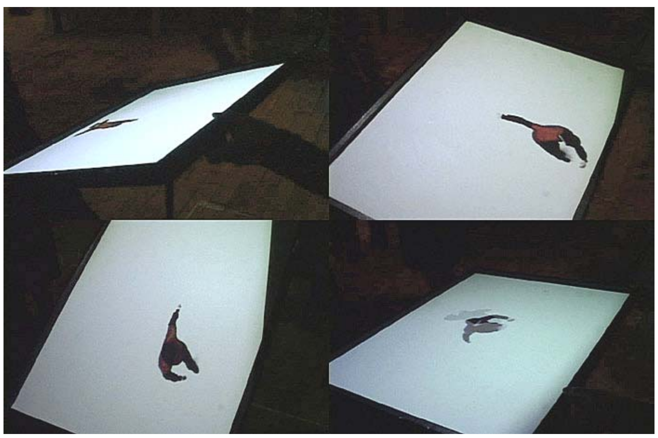

Figure 3. The virtual character slides towards the downward leaning corner of table if the user tilts the tabletop.

Navigable Information Spaces

As mentioned above, tangible moveable interfaces can be used as tools for information navigation, such as maps, menus and lists. The two applications described here use our tilting table to navigate different kinds of information spaces. The common characteristic across these two examples is that the information space must be conceptualized as a surface in order to map to our tilting platform.

Tiltable Maps

This application adds a tangible experience to the process of browsing a map (Figure 4). Users can control the sliding direction of a map view by tilting the tabletop in the appropriate direction. This presents a new interactive experience as compared to the traditional map browsing in Graphical User Interfaces, where dragging or clickable buttons are used to control the direction and movement.

The tilt-angle of the tabletop is used to control not only the direction, but also the speed of the map-sliding (the greater the angle of tilt, the faster the map will slide). The application provides access to a global repository of world maps by connecting to the Google Maps server online in real time. Other map sources could be linked to the setup if desired.

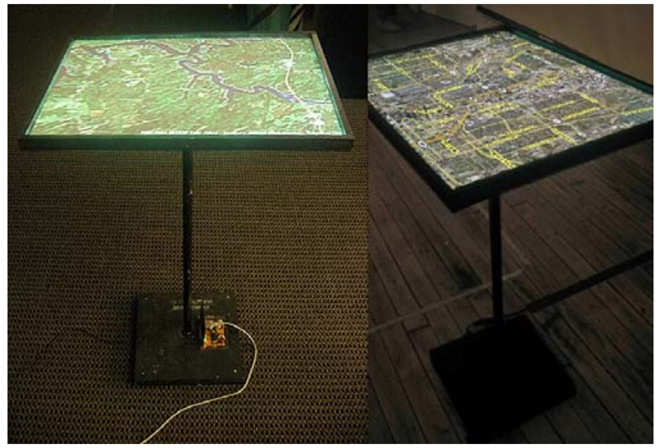

Figure 4. Map can be navigated through the tilting tabletop.

BioBroswer: bug crawl

The BioBrowser project seeks to use tangible interaction techniques for collaborative browsing and searching of large biological information databases, for example in educational contexts. As a part of this work, the *BioBrowser: bug crawl* piece uses the tilting table to let users explore the surface of any animal from the perspective of a tiny insect. Our current prototype allows users to explore information about the different parts of an iguana, shown in Figure 5. Users physically tilt the table's display to move around the animal's surface. The application program is implemented in Java and OpenGL.

Our long-term goals for BioBrowser are to create tangible tools that can bring together biology education and biological inspired design processes.

Figure 5. Users can navigate the skin of an Iguana.

USER INTERACTION AND FEEDBACK

Over the course of our research thus far, some common themes have begun to emerge based on user feedback about our four different applications. Most users comment that they enjoy the novelty of interaction that is provided by the moveable tabletop surface. We have found that users quickly grasp how the interface works after tilting it in different directions once or twice, which suggests the interaction is intuitive. They also enjoy seeing information normally seen on desktop displays presented in a new way.

Specific feedback varied across the different applications, as each one provided a different kind of experience for users. For example, with the *Tiltable Maps* application, some people experienced confusion as to their point of view with respect to movement across the map, i.e. were they moving on the map, or were they sliding the map itself. Most users assumed they were moving on the map, and so if they wanted to go to the West, they tilted the West side of the map down. A few users however, assumed they were sliding the map the way objects would slide on a tilted surface. So when they wanted to go to the West, they pushed the opposite side of the table down, since they thought the map would slide to the down-tilting side and thus reveal more map to the West. One person expected that lifting the table surface toward them (tilt left-side up) would zoom the map. Others noted the lack of zooming as well, suggesting that it was an expected feature for map-based navigation.

The *BioBrowser: bug crawl* application prototype was shown at an International Symposium for Biologically-Inspired Design and Engineering in the spring of 2006. This allowed us to get feedback from biologists and engineers on the interface concept. These users liked the interaction metaphor of crawling around the skin of an animal, and suggested that it could be further enhanced using a touch-sensitive surface on the table. This would allow them to query specific parts of the animal for further information, or perhaps reveal layers underneath the surface of the skin.

Finally, for some of the applications, people commented that they did not like the distortion of the image projection. On the other hand, with the expressive artworks, several people noted that distortions of the image due to projection produced an aesthetically pleasing effect, calling attention to the relationship between virtuality and physicality.

FUTURE WORK

Based on early reactions to our prototypes, we think promising additional functionality for our next version would include ways to zoom the image by pushing on or lifting the tabletop, as well as the addition of a touch-sensitive surface. These would require additional sensing technologies, which we plan to add to our current version of the platform.

Additionally, in order to solve the noticeable projection distortions that arise in some types of content, we might try to correct the image via computational adjustments. We are also interested in mounting LCD screens on the system to eliminate the need for overhead projection. This would also allow for an all-in-one design and would take care of the need to calibrate the system upon each set-up.

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