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The Evolution of Tangible User Interfaces on Touch Tables: New Frontiers in UI & UX Design

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The Tangible Engine Visualizer, which comes with the Tangible Engine SDK.

Multitouch tables and displays provide important benefits for users in museums and other public spaces, including using flexible, reconfigurable platforms to present information and experiences and allowing multiple users to explore content simultaneously (Creed, Sivell, and Sear, 2013; East, 2015). Using physical objects in conjunction with multitouch tables has been possible since the first such tables were developed a decade ago. In fact, the value of receiving tactile feedback and being able to enter or manipulate information while looking at a screen have been recognized since computer interfaces were in their infancy (Weiss, Wagner, Jansen, Jennings, Khoshabeh, Hollan, & Borchers, 2009). However, the development of tangible-object interfaces picked up speed with technological advances leading to a broader range of touch-sensitive input devices.

Some early systems, such as the Microsoft Surface (introduced in 2008), were projector- and vision-based systems with cameras that could detect any number of objects. Some systems, like Reactable, still use this method; their unique music-making software relies on the detection of many tangible objects. On the other hand, Sony's Smartskin, which debuted in 2002, was not camera-based but instead used capacitive sensing to calculate the position of a user's hand in relation to the surface. As Ion notes in a 2013 Ars Technica review, creative developers explored a range of technologies to make touch-based input flexible and economical throughout the early 2000s. One of the most challenging aspects of this experimentation centered on finding intuitive ways to conceptually link tangible objects and their digital counterparts and outcomes. As Ishii (2008) notes, "the design challenge is a seamless extension of the physical affordances of the objects into the digital domain" (p. xv).

Our company, Ideum, has been exploring the world of tangible object-recognition interactives for just the last few years. While we have been building multitouch tables for almost as long as Microsoft (we began in late 2008), our primary focus has been on developing robust systems for public spaces. By the time we turned our attention toward exploring tangibles, the core technologies had evolved. The move to LCD and the elimination of cameras limited object-recognition options. It wasn't until our Dynamic Desktop experiment in 2014 that we began to develop a system that worked with new LCD-based projected-capacitive touch systems.

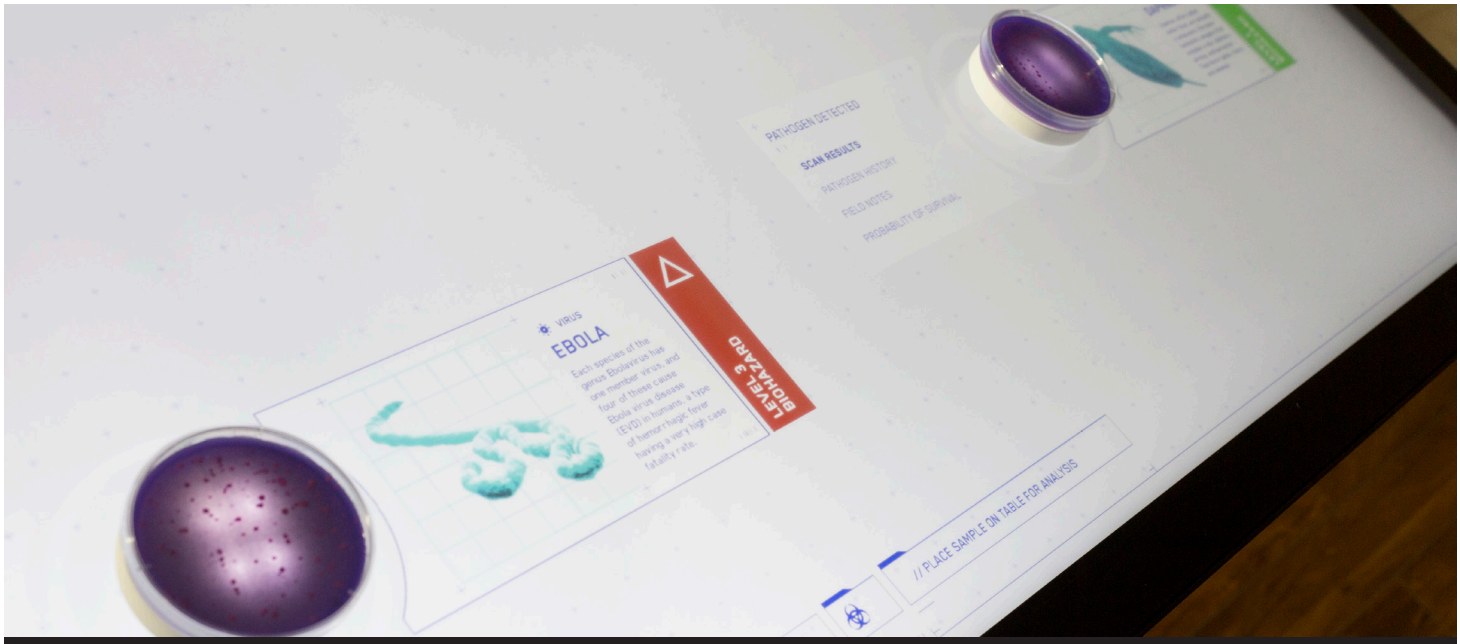
Projected-capacitive touch uses anything that holds an electric charge, like a finger, to detect touch. Our Dynamic Desktop experiment and our Tangible Engine software were designed to detect objects with conductive patterns on projected-capacitive touch screens. While there are some limitations in terms of the number of objects supported, this system has the advantage that it can be a plug-and-play option usable with the latest 4K UHD displays equipped with projected-capacitive touch technology.

The Power of Objects

Science museums have long championed physically interactive exhibits as an important way to engage visitors. In fact, research supports the idea that active inquiry and hands-on exploration can deepen investigation and reflection, promote social interaction, and ultimately enhance learning and retention (e.g., Allen & Gutwill, 2004; Hein, 1998; Simon, 2010). In fact, such interactive approaches to learning have migrated beyond science centers to museums focusing on art and history, sparked the burgeoning "maker movement" through which people learn by designing and creating devices, and circled back to the classroom to push formal teaching methods beyond older didactic approaches.

Tangible user interfaces (TUI) have become an increasingly common way of building interactivity into digital experiences. TUIs on touch tables provide a physical interface for screen-based two-dimensional experiences. Interestingly, for many years, particularly as the touch table form factor was emerging, many applications presented visitors with "quasi-physical" experiences in which users manipulate onscreen digital objects as a primary interface. Digital objects allow multiple users to interact simultaneously and can be used in creating touch table applications that are omni-directional. But digital objects have another important impact: they invite people to treat the experience interactively, rather than as a simple information delivery system, and thus to explore content more deeply and connect the digital experience to their own lives. In many cases, they are designed to look like objects in the physical world, such as photos, documents, devices, or other items. And, of course, tangible physical objects used in TUI-based exhibits are objects in the real world. They are persistent, and if presented correctly, create no ambiguity in terms of their use and function.

Tangible interface objects can take many forms. There are some technical requirements in terms of the conductive materials used to create the patterned "puck" recognized by the system (and its minimum diameter is approximately 2.75 inches), but a variety of materials, 3D designed objects, and other items can be placed on top of these tangible pucks. For example, we've designed wooden coffee coasters, add-on pucks for wine and beer glasses, custom 3D-printed objects, and a variety of acrylic "totems." Some of our totems contain real objects (such as medical devices); others are more symbolic, representing brand identities or concepts tied to content found on the touch table. Whether they are real or symbolic, however, these objects add additional context and meaning to the visitor experience.



A microscopic pathogen discovery experience where users interact with illuminated petri dishes.

Design Approaches

We've now built a dozen applications using tangible interfaces on our multitouch tables. While each is unique, these experiences fall broadly into two main interaction categories: *object-follow* and *object-activation*.

OBJECT-FOLLOW EXPERIENCES

As the name suggests, in object-follow experiences, interface elements and content follow the tangible around the table. These applications almost always involve multiple users, and because information is provided anywhere on the table surface, designs need to move and shift to accommodate placement. This can present challenges in applications using smaller tables or many users.

We've created several object-follow experiences that use tangible coasters or beverage glasses for beer, wine, coffee, and other tastings. This type of interaction seems to work well for beverages or dining, as having the tangibles closely tied to the items visitors use as they drink or eat provides contextual information that can enhance the sensory experience.

We've been working with Starbucks on an application that showcases this method for the last two years. The experience focuses on the origins of their roastery coffees. Learning the story of where these coffees come from, how they are grown, and how Starbucks selects coffees and growers can enhance the coffee-drinking experience. In addition, visitors learn about Starbucks, their process, and their values, all while enjoying a speciality coffee. As we've conducted research with Starbucks, we've been improving the application and its interface—including improvements to the tangible objects themselves, moving from 3D-printed plastic tangible coasters and add-ons to the bottoms of Starbucks coffee cups to weighted, laser-etched wooden coasters.

An interactive beer tasting in which each glass brings up different tasting notes.

OBJECT-ACTIVATION EXPERIENCES

We call the other main interaction type object-activation. Here, the placement of a tangible initiates an interactive experience or the presentation of content. With this design approach, the content doesn't follow the tangible. Usually, a fixed area on the screen is designated for those types of applications, and content is "activated" as the object is placed on the table. Placing a different object or totem changes the information presented. Larger objects are often used for these types of experiences, and activation areas are usually placed on the side of the screen to give users room to interact with on-screen digital elements.

When using these larger objects, or totems, consideration should be devoted to where they are placed when not on the table. We've designed custom totem holders that attach to the side of the table, and even some with RFID and LED lights to indicate they are active.

These kinds of experiences have been quite popular among our Fortune 500 clients to demonstrate corporate initiatives, show solutions for complicated industrial processes, teach doctors about new pharmaceuticals, share information about innovations in medical devices, and promote new and emerging products. Ideum has not yet deployed an experience using this design approach in the museum world, but with the release of our Tangible Engine SDK, we know that other design firms (such as Stimulant in San Francisco) and museums are beginning to experiment with new applications as well. We will provide more examples as they become available.

A prototype with a large acrylic totem.

The Future of Tangible Interaction

One of our favorite examples of early tangible interfaces came from a partnership between Aachen University and UC San Diego (Weiss et al., 2009). Called Slap Widgets, the concept involved developing a series of widgets out of flexible silicone and acrylic that would act as physical interfaces on tabletop displays using computer-vision systems. These widget keyboards, keypads, knobs, and sliders provided users with familiar interface elements (the researchers point out that this familiarity "helps the user to grasp their intended function," p. 485), although the way they were used is in these contexts is novel.

Since most of the applications Ideum develops are used in public settings, knobs and sliders are much more relevant to our work than keyboards and keypads. (Unlike firms focusing on more academic products, we rarely develop applications that require users to type.) In addition, these interface elements are commonly found in audio and lighting-control software. However, Weiss et al. note that "using them is difficult when there is no tangible control" (p. 485). This highlights a key principle guiding tangible development: when possible, the way tangible interfaces are used should build on already well-learned manipulations of more classic interface types. As one research participant noted, "widgets map well-known physical control elements to their virtual equivalents and may be particularly well adapted for people not familiar with virtual controls" (p. 489).

These ideas have inspired some of our latest innovations. We've begun to experiment with conductive materials, 3D-printed parts, and industrial control knobs to create our own "widgets" to work with our projected-capacitive touch tables. Since these tables use conductive materials rather than cameras, and these materials are not only opaque but usually black or gray, we cannot utilize colors or other graphic indicators in the same way as our Slap Widget predecessors. (Acrylic and silicone illuminate, and fabulously so.) However, nearly a decade after Slap Widgets arrived on the scene, advancements in 3D printing, new microcontrollers, and tiny LEDs are now available, and we are beginning to incorporate those technologies into new tangible designs.

From a software standpoint, we've made a number of improvements to our Tangible Engine SDK. Version 1.5 is faster and more reliable, and it also includes new features, including multi-screen support and absolute orientation. (See our Tangible Engine wiki for more information.) In addition, we've introduced the Tangible Engine Media Creator. It has a GUI and a drag-and-drop interface that allows for rapid prototyping. At present, it can only be used to create object-follow applications. However, having a tool that allows for rapid prototyping and quick evaluation is important for developing these types of experiences. The easier an application is to develop and deploy, the more examples are built, leading to additional feedback and the further development of interface and design standards.

Ideum has begun experimenting with dials and other more dynamic tangible objects.

The blending of physical and digital interfaces has the promise of creating more fluid, dynamic, and ultimately engaging user experiences. However, this is not without risk. While providing interactive options can prompt deeper investigation and enhance learning, that learning may be limited to very specific contexts. As Nina Simon notes in The Participatory Museum (2010), "interactive exhibits, when successfully executed, promote learning experiences that are unique and specific to the two-way nature of their design" (p. 5). More broadly, increasing interactivity can sometimes lead to applications that are confusing or overwhelming (Allen and Gutwill, 2004). Developing successful applications that use tangible objects on touch tables requires finding a balance between familiar and natural interactions while still presenting new and compelling visitor experiences. We are excited to design and build the tools to make these experiences possible—and to work with other creative organizations to push the boundaries of tangible user interfaces.

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About Ideum & Tangible Engine

Ideum is an innovative design company based in Corrales, New Mexico. The firm focuses on creating the next generation of visitor experiences that blend the physical and digital realms. Along with its Creative Services software group, Ideum designs and produces integrated and hardened large-scale multitouch tables and touch walls for museums, educational institutions, government agencies, and Fortune 500 companies. It has developed multitouch tables and screens since 2008, and its products have been sold in more than 41 countries. Tangible Engine makes it easy to create tangible user interfaces (TUI) for multitouch tables. It is designed to work exclusively with Ideum multitouch tables. Tangible Engine is the first product of its kind to work with projected advanced capacitive touch screens. Tangible Engine release 1.5 now includes multi-screen support and improved tracking fidelity.

For more information, please visit www.ideum.com and www.tangibleengine.com or contact Esther Lombardi at (505) 792-1110 ext.1.