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Interactive Tabletop Exhibits in Museums and Galleries

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Just as online shopping is a bellwether of advanced online technologies, so do museums and galleries showcase the best in computer display and interface technology. In the first case, commerce demands that speed and reliability get priority; in the latter, technological invisibility is foremost. The museum experience is an unusually tactile, sensual one, and the standard keyboard-mouse-and-screen setup might seem out of place. Further, while "museums tend to draw educated visitors,"[1] not all "educated" people are computer literate. For these reasons, museums and galleries have actively sought out creative interface systems to encourage interaction with computer-mediated displays, while keeping the technology in the background.

This trend toward sensual involvement is particularly noticeable in tabletop displays, as they appeal to two aspects of familiar daily life: the horizontal surface as a workspace, and hand gestures (or common objects) as tools for manipulating information. Of the nine exhibits I surveyed for this article, only one used anything resembling a mouse, and the two others that used physical objects for mouse-like functions did so in a disguised fashion. Another exhibit used radio frequency identifier (RFID)-tagged paper as a physical token, and flashlights as surrogates for shovels. Overall, the systems seem to consciously strive to return the desktop metaphor back to its roots in the physical, corporeal world.

(Courtesy Indianapolis Museum of Art, Pervasive Technology Labs at Indiana University)

1 etx shows connections between artworks that might not be immediately obvious.

The exhibits

In choosing the exhibits to feature in this article, I concentrated on those that

- have been accessible to the public, even if only briefly;
- used a horizontal display surface;
- were displayed in a museum or art gallery; and
- substantially incorporated computer technology for I/O systems.

Undoubtedly, there are many exhibits that I simply didn't know about and others that blur the lines of several of these criteria. For example, among the exhibits featured in this article, should the Dialog Table (which has a slightly inclined surface) be considered horizontal? What about exhibits that use both horizontal and vertical displays, as does etx? What about artwork where visitor interactivity is limited to sitting down at a table and pouring cups of tea (Individual Fancies; see http://www.berylgraham.com/cv/sub/fancies.htm)? In the end, we must acknowledge that this list is merely representative, not comprehensive. (A remarkable list of interactive tables in general is available at http://tecfa.unige.ch/perso/staf/nova/blog/2005/01/10/space-and-place-a-list-fo-interactive-tables/.)

etx

etx (see http://www.ima-art.org/xRoom.asp#etx) is an art exploration system that uses an infrared camera system to track reflective-taped wooden paddles on a table surface. Located at the Indianapolis Museum of Art, etx uses the PercepTable recognition and display system—developed at Indiana University's Visualization and Interactive Spaces Laboratory, which is part of the Pervasive Technology Laboratories. The table itself was provided by Eames Office (see http://www.eamesoffice.com), hence the "et" part of the name stands for Eames Table. User input affects projections

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both on a nearby wall and on the table itself. Up to three visitors can participate simultaneously, from any side of the oval table, and usage is tracked in a relational database. (These data can later be used in policy decisions: if visitors tend to click a lot on Victorian clothing, for example, an exhibit could be planned to feature such items in the collection.) Figure 1 shows an example of a central graphic paired with other examples that show interiors, are post-Impressionistic, or are dominated by the color red. The "?" paddle displays further details, the arrow paddle indicates the work's physical location in the building, and the "X" paddle shows connections with other works in the collection. PercepTable was first demonstrated at the Supercomputing Conference (see http://supercomp.org) in 2002 and again in 2003 before being deployed in the field; it's now also used at the Indiana State Museum to educate visitors about local water flow and use.

Asia Society and Museum display

A permanent display (see http://www.asiasociety.org/about/buildingtour/) at the headquarters of the Asia Society and Museum in New York gives a visual way for visitors to explore six aspects of Asian culture, region by region. A small, round table supports six palm-sized stones, variously labeled food/cuisine, news, art, country profiles, Asian Americans, and Asia for kids. A map of Asia is projected from above onto each of the table's two placemat areas. Visitors manipulate the display by moving the relevant stone to the part of the map they want to examine (the image is projected onto a hidden Wacom tablet). Figure 2 shows Wacom mice disguised as the labeled stones.

Churchill Lifeline

The Churchill Lifeline is a permanent, central exhibit at the Churchill Museum and Cabinet War Rooms (visit http://www.churchillmuseum.iwm.org.uk) in London. Projected from above onto this 40-foot-long table are summaries of events in the statesperson's life, arranged in chronological order. A series of touchstrips (force-sensitive resistors) on both long sides of the table gives visitors greater detail about these events, via access to more than 4,000 relevant digital documents. Figure 3 shows the 16-inch strips, which visitors touch to change what information is displayed. The image surface, which is projected from overhead, is not itself directly interactive.

Illuminated Manuscript

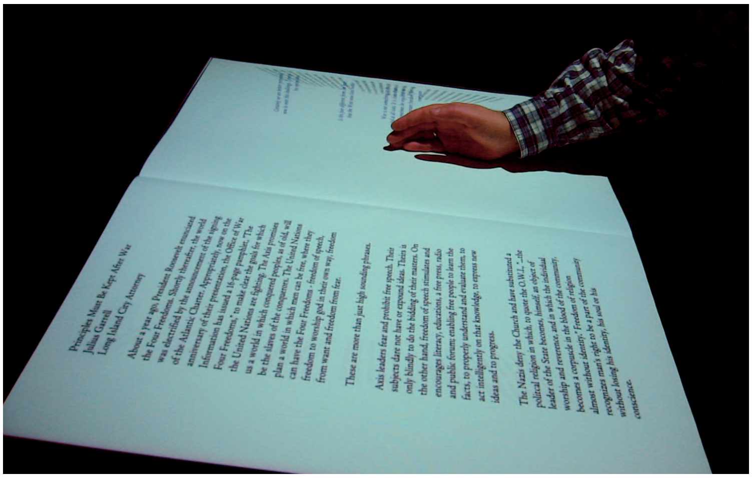
Illuminated Manuscript, an artwork created for the 11th documenta exhibit in 2002 is a coordinated collection of art showings that usually occurs every five years in Kassel, Germany (visit http://www.davidsmall.com/manuscript.html). Designed by David Small, it comprises a lectern-supported blank book with text projected upon it from above. As visitors turn the pages and move their hands over the book(see Figure 4), they "disrupt, combine and manipulate the text on each page." A later version of the Illuminated Manuscript became part of the permanent exhibit at the Nobel Peace Center in Oslo, Norway, at its opening in 2004.

(© Small Design Firm)

2 **People using an interactive tabletop exhibit at the Asia Society and Museum.**

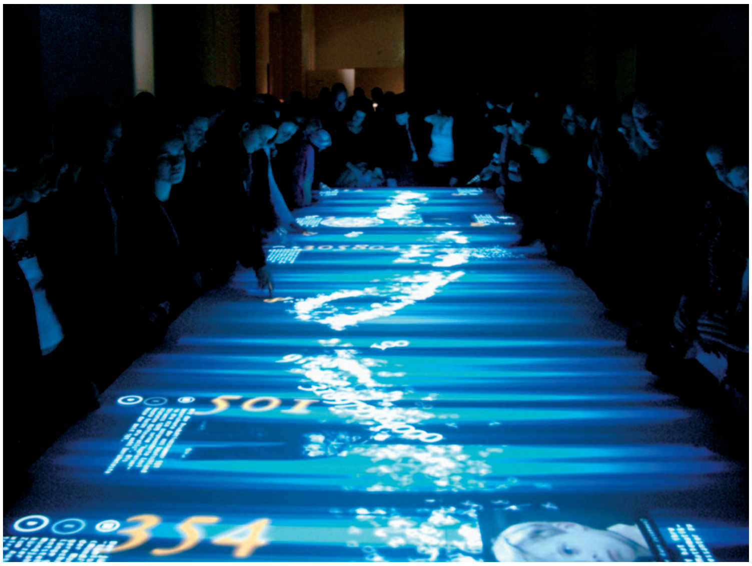
(© Small Design Firm)

3 **A section of the Churchill Lifeline, at the Churchill Museum and Cabinet War Rooms.**



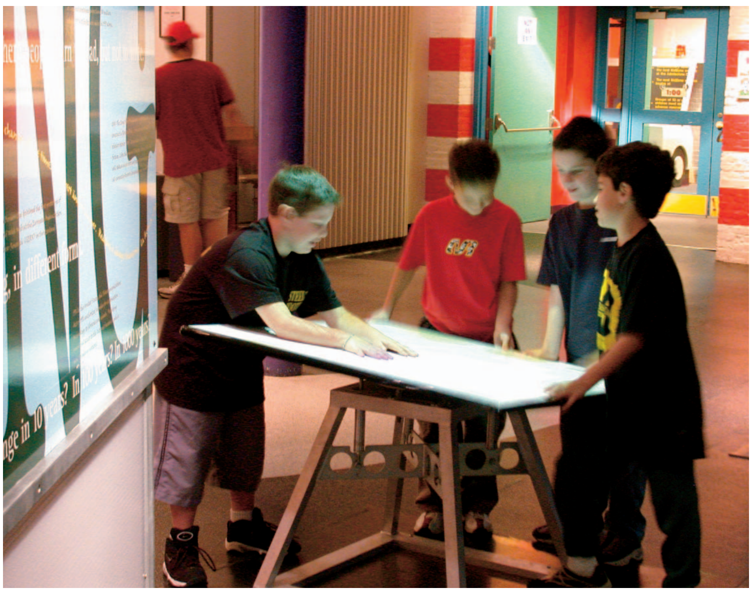
(© Small Design Firm)

4 **A detail of Illuminated Manuscript, an artwork that uses overhead projection onto a blank book to "explore the communicative possibilities of spatialized language in the electronic media" (see http://www.davidsmall.com/manuscript.html).**



(© ART+COM)

5 **The floating.numbers display at a 2004 show at the Jewish Museum Berlin. A river of numbers streams by visitors; touching any of them reveals its meanings in Jewish history and culture.**



(Courtesy Onomy Labs)

6 **Children playing with a museum installation of Tilty Table, which enables display of oversized, 2D information. Visitors scroll in any direction by physically tilting the table: the image runs down the decline, as though affected by gravity. Later versions incorporated a "zoom" feature, which was effected by twisting the tabletop.**

Un-Private House

A table at The Un-Private House, a 1999 exhibit at the Museum of Modern Art in New York, acts as an information center within a larger exhibit about architecture (visit http://www.moma.org/exhibitions/1999/unprivatehouse/for more information). The table invited visitors to sit at any of eight projected placemats around a large, round table. A lazy Susan in the middle of the table held 26 coasters, one for each part of the exhibit. By placing any one of the coasters on a labeled space in the placemat, the visitor gained more information. The exhibit's welcome mat also used interactive, horizontal sensing and display technology, appearing to react to visitors as they stepped across it.

History hunt game

A history hunt game, intended mostly for children, was a temporary part of an exhibit at the Nottingham Castle Museum and Art Gallery in England. Two parts used interactive horizontal displays. The first was the Storytent, where RFID-tagged paper placed on a turntable unlocked projections on the walls of a tent. The exhibit uses a paradigm similar to one described elsewhere.[2] Spinning the turntable changed the projection as if the viewer is looking around a 3D virtual view of the castle as it appeared at some point in history. Another part of the exhibit, the Sandpit, engaged visitors to dig for clues in digital sand, using a flashlight beam as if a shovel.

Dialog Table

The Dialog Table (see http://www.dialogtable.com) at the Walker Art Center in Minneapolis, Minnesota, presents further insight into items in the center's collection and serves to stimulate discussion among visitors. Part of the permanent exhibit, it's one of the few tabletop displays to use rear projection: images are projected via a system of mirrors inside a kiosk onto two horizontal, head-to-head displays. A smaller, portable version, Demo table, has also been built.

floating.numbers

floating.numbers is an associative presentation of information that's part of a temporary exhibit at the Jewish Museum Berlin (see http://www.artcom.de/index.php?option=com_acprojects&page=6&id=14&Itemid=144&details=0&lang=en). As with the Churchill Museum exhibit, this was a long (30-foot) table. But there the similarity ended: instead of a static chronology, floating.numbers presented a dynamic river of digits that flowed from one end to the other. As Figure 5 shows, visitors could reach in and grab a number with their hands, making the display show those numbers' associations in Jewish history and culture. The image is projected from overhead, while a scalable array of capacitance sensors monitors touch. This exhibit was also unusual in that it incorporated a touch-sensitive control on a large scale: most other tabletop displays either use touch sensitivity in a limited area, or interpret user actions via some sort of gesture-recognition technology.

Tilty Table

The Tilty Table by Onomy Labs (see http://www.onomy.com/blue/tilty.html) is part of the permanent exhibit in several museums, including the Tech Museum of Innovation in San Jose, California; the Maryland Science Center in Baltimore; and the Singapore Science Center. It resembles a drafting table resting on central pivot points, such that it can be tilted in any direction (see Figure 6). Doing so causes the image projected on it to spill in that direction, as though gravity were pulling it down. As a result, the entirety of oversized displays (such as maps) is available in a comparatively small space. More-recent developments from Onomy include Twisty Table, where you zoom the image by partially spinning the table; and Spinny Table, in which the table truly spins around a central pivot.

Public benefits

The benefits of publicly accessible computer kiosks have been evident since the 1972 debut of the first electronic bulletin board, Community Memory, in a public kiosk outside Leopold's Records in Berkeley, California. A short oral history of this system's creation is available at http://oldeee.see.ed.ac.uk/online/internaut/internaut-01/comm.html, and an article about its creation is available elsewhere.[3] But why use tabletop displays? In my survey, two reasons stand out. First, table- top displays encourage a homier, more-familiar, collaborative atmosphere. Several of these exhibits take advantage of the face-to-face experience you get by working around a table with other visitors. All the systems I found, except the Illuminated Manuscript, are designed so that visitors approach them from several angles, and all can accept simultaneous multiuser input. Some further the "gather 'round the table" feeling by incorporating noncomputer metaphors, such as the dining room table (with coasters!) of the Un-Private House and the Sandpit of Nottingham Castle. Second, tabletop displays can have a greater interactive area than vertical displays, which are more bounded by the human body's limits: we can't comfortably reach items lower than two feet or higher than seven feet above the ground, nor can we hang from the ceiling to come at the display from another angle. The Churchill Timeline and floating.numbers exhibits demonstrate the utility of horizontal displays for oversized interactive information. The Tilty Table and its followers demonstrate another approach—but not one that necessarily needs to be horizontal.

Tabletop displays encourage a homier, more-familiar, collaborative atmosphere and provide the ability to increase a display's interactive area.

In discussing the floating.numbers exhibit, Anna Schäfers of ART+COM echoes statements made by other interactive tabletop designers:

> The visitor response was very good … [floating.numbers was] so easy to use and offer[ed] information so playfully that visitors of all age groups tried it without being afraid of the technology. The directness of the interaction (no other device but your fingers were needed) and the fact that as many people as found space around the table could use it simultaneously made it very popular.

Risks to public displays

As these were all designed to be public exhibits, physical and technical sturdiness was a high priority. One result is the prevalence of ceiling-mounted projectors on ordinary table surfaces, with data streaming to and from a distant or protected computer. Thus, the only parts the museum visitor has access to are comparatively low-tech and indestructible—that is, the table surface. Experience with etx bears out the success of this approach. Indianapolis Museum of Art's project manager, Rob Stein, reported, "Both installations run completely unattended and require no additional calibration or tweaking after the initial setup."

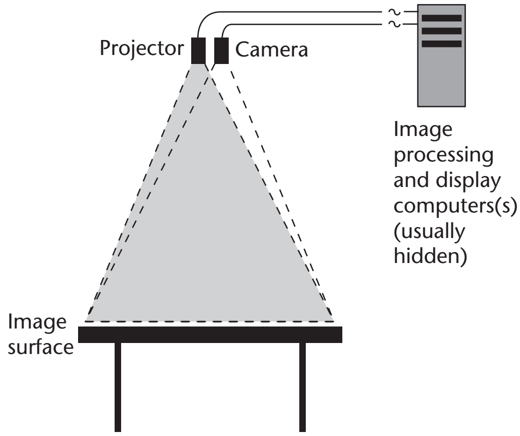
An interesting exception to the plain-table paradigm is the Tilty Table, in which movement sensors are by necessity part of the table itself. Onomy chief technical officer, Scott Minneman, commented, "It's not unusual for us to see a kid lying on the table and having their friends tilt it, so they're flying over the exhibit. They use it like a gymnastic apparatus." Its creators protect the table's sensitive innards by overbuilding. They centered the table's mechanical system around a universal joint from the automotive industry. Minneman claims that their tables haven't experienced any abuse-related mechanical failures, despite more than three million visitors at several museum sites.

Theft is another danger. While none of the exhibits is portable enough to steal in toto, three of them incorporated parts that could be removed: the Asia Society and Museum exhibit (stones containing Wacom mice); etx (paddles that function as mice); and Nottingham Castle (paper, RFID tags, and flashlights). In the Asia Society case, there's no special protective system other than museum security, which was apparently sufficient. (Creator David Small noted that none of the stones have been stolen since the exhibit opened five years ago, although several had to be replaced, typically after being dropped or thrown onto the room's hard stone floor.) etx avoided the problem by putting the intelligence in the gesture-recognition technology and keeping the paddles themselves dumb: they're essentially just blocks of wood with reflective tape on them, so theft of a paddle would be a fairly inexpensive loss. The Nottingham Castle exhibit, which was mainly aimed at children, relied heavily on adult interaction to reclaim the flashlights and RFID tags when the children were done with them. The paper itself was intended to be a take-away souvenir.

The art of seeing

The surveyed systems are fairly similar in terms of output technology. Except for the Storytent section of the Nottingham Castle Museum and the Dialog Table, they all used overhead projectors (see Figure 7 on the next page) to put images onto a table's horizontal surface. But input systems tended to fit into one of three categories: vision technology (seeing), capacitance sensors (touch), and a variety of specialized systems based in hardware.

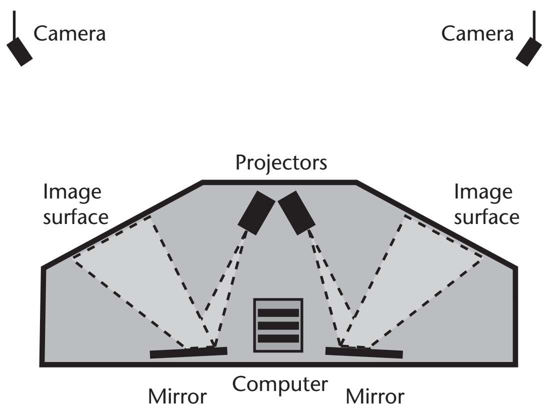
Vision technology is the most commonly used—showing up in five of the systems mentioned here. While difficult to perfect, it offers a few notable advantages over



7 **A simplified diagram of how a typical vision/projection system works. A camera is calibrated to see what part of the projected image is being affected. That information is fed back into a computer, which might change the display or perform other functions, such as make a database entry. Some such systems rely on the camera seeing specific objects, such as specially prepared paddles; others look only for hands.**

touch-based systems, namely, it's scalable (large surfaces aren't substantially more challenging or expensive to manage than small ones); hardware failure is unlikely to result in dead spots in the exhibit; and, as mentioned earlier, it distances sensitive technology from the public's unpredictable actions. On the other hand, touch-sensitive systems have other advantages: capacitance-measuring technologies, such as in floating.numbers and the Un-Private House, would be more appropriate for specific applications, such as those where touch happens on several surfaces.

Four of the surveyed examples use both overhead projection and vision input, with the typical configuration employing a side-by-side, ceiling-mounted projector and camera. At first glance, a designer might be concerned with alignment problems that could occur in vision systems because the projector and camera have different points of focus. In practice, however, it doesn't present a problem, for two reasons. First, the parallax created by having the two devices a few inches apart is comparatively minimal. Second, such systems need be calibrated only once, as long as neither instrument nor the table is moved.



8 **The vision/projection system used by Dialog Table. Like the overhead system described in Figure 7, this one looks for action at the display's surface. But by using rear projection, visitor interaction throws no shadows on the image itself.**

A second potential problem from such systems is that users' shadows could obscure the display area that they're trying to manipulate. But in the field, shadows didn't cause substantial interface problems. As Onomy's Minneman said:

> We thought shadow was going to be a big issue, but it's turned out not to be. For one thing, the image coming from the projector is a cone, so your head and body don't throw a shadow, only your hand when you point at something. And when you point at something, it's the thing out at your fingertips that you want, so you don't notice what the rest of the hand is blocking. Plus you can see the image on your hand.

One system, Dialog Table, avoids the issue entirely by using a rear-projection system on a kiosk-like table. Advantages to this approach include a lack of shadows on the image, and more of an all-in-one design. On the other hand, image size is more limited than in overhead-projection systems (see Figure 8).

Touch and presence

The second input-system category involves measuring touch or presence, whether via a hardware device (such as a pen or mouse) or by a part of the human body. In this area, we see greater variety and more special-purpose solutions. The floating.numbers project has the most extensive type, as it allows touch sensitivity over the entire display surface. According to ART+COM, floating.numbers uses a capacitive sensor technology—Sensitive Skin, invented and patented by the company—that can make surfaces of any size interactive, and with as many simultaneous users as is physically practical.

The placemats for the Un-Private House are also presence sensitive, using an array of discrete electric-field sensing devices. These tauFish sensors, perfected at the Massachusetts Institute of Technology Media Laboratory for the Un-Private House, are small circuit boards, each sensing the capacitance of four 1.5×1.5-inch electrodes. A placemat in the exhibit comprises 30 such devices in a 5×6 array, so the sensitive area totals approximately 18×15 inches.

The Churchill Lifeline display uses a simpler form of touch sensitivity. In this case, the main table surface isn't sensitive, but the table edges are lined with 16-inch-long linear potentiometers. These force-sensitive resistors return an analog value that is then sent to the controlling computer as a 10-bit digital number.

The Asia Society and Museum exhibit uses hardware devices for user input. The system projects the image from above onto a placemat-like area. Underneath the placemat is a Wacom tablet built into the table, while the stones that are moved to various areas of the display are Wacom mice. According to Wacom, all their tablets use electromagnetic resonance send-and-position sensing technology, which they've branded Penabled. (A detailed summary of Wacom's tablet technology is available at http://www.wacom-components.com/english/tech.html.) The tablet/placemat contains several layers of energized antenna coils, while the mice/stones contain tank (or LC) circuits, which act as resonators. From there it's a simple matter for the hidden computer to match rock position to the projected image.

The coasters in the Un-Private House display use a similar system to that at the Asia Society and Museum. The 26 coasters contain RFID tags with LC resonators that were hand-built from printed copper coils. As in the Asia Society and Museum exhibit, the user is presented with a placemat metaphor, but this time only one section of the placemat (the upper-right corner, where a drink would naturally be placed) is responsive to the coaster. This area has a tag reader—based on a single-turn antenna and a directional coupler—to measure its change in load when a resonator (coaster) is present.

Finally, some exhibits use other technologies to accept and mediate input. For example, each placemat in the Un-Private House exhibit includes a send-to-center button that moves the information currently displayed on that placemat onto a central lazy Susan. When the user rotates the lazy Susan, the image rotates as well, so others around the table can examine it in its correct orientation. The lazy Susan contains a stationary sensor with phototransistor/LED pairs, shining through a perforated ring that rotates with the lazy Susan's surface. The sensor notes the passage of the perforations, sending strings of ASCII L's and R's (for left and right movement) to a computer, which then redraws the display accordingly.

The Sandpit area of the Nottingham Castle exhibit featured an unusual user interface that mimicked an analogous activity—uncovering buried clues in the sand. Gustav Taxén, who worked on the exhibit, describes it as follows:

> The sandpit ran on a (for its time) high-end PC and used a projector mounted in the ceiling. We created a square projection area on the floor using a white plastic material and we dressed the edges of it using black velvet, sand, rocks, and stuff like that. There was also a Web cam mounted next to the projector, and we used a homemade image analysis application to identify the flashlight hotspots. The virtual sand itself was rendered as a height field (seen from directly above), which was animated using a variation of a water surface simulation (with a viscosity set so that the movement was quite slow). The surface level was lowered locally (dug) at grid positions where the flashlight hotspots overlapped. The entire sand heightfield also slowly returned to its original height over time.

Conclusions

It can be difficult to judge a project's success based on statements from its creators because they have a vested interest in seeing the project as a success. But in the case of the interactive tabletop displays I surveyed, the form's success is clear. These tables are approachable in ways that the standard keyboard-and-screen computer isn't. A large part of that success is certainly due to its novelty, which might wear off in time. A large part appears due to the high level of quality in software and interactivity. Indeed, it would make no sense to use inexpensive approaches on these facets in a new system, where the hardware is comparatively expensive in both time and money and the user interface is a central goal. But ultimately the exhibit content is what makes the exhibits unique and is the basis for their appeal.

Customer opinion drives museums, as with any other businesses, and the public has spoken. It wants a museum visit to remain sensual, visceral, and direct—in short, unlike sitting at a computer. By moving the orientation of the digitally interactive experience, museums are answering the call. ■

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