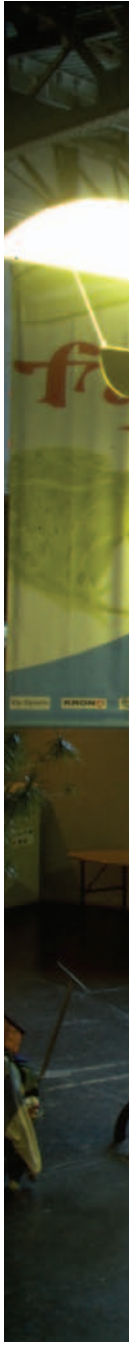
By Sherry Hsi and Holly Fait



Interactive RFID-enhanced museum exhibits let visitors continue their scientific exploration beyond the museum's walls. But museums must still help them understand the technology and address their data privacy concerns.

RFID Enhances Visitors' Museum Experience at the Exploratorium

With the emergence of increasingly affordable RF tags and RFID readers, RFID technologies have now made their way into end-user applications in museums and other educational settings. Here, we explore a custom-designed RFID application called eXspot being prototyped and evaluated over the past three years at the Exploratorium, a hands-on science museum in San Francisco. We also share a variety of RFID configurations in other museums and speculate about their wider implementation and implications in the museum community in the U.S.

The eXspot system consists of a small RFID reader package for mounting on museum exhibits, an RF tag carried by visitors on a card or necklace, a wireless network, a registration kiosk, and dynamically generated Web pages. Co-developed by the University of Washington's Computer Science and Engineering Department, Intel Labs Seattle, and

Exploratorium floor and exhibits, San Francisco

the Exploratorium, the plastic-molded RFID reader package contains a Crossbow Mica2Dot mote (433MHz) for control and radio connectivity, a low-power RFID reader with a range of a few inches (for 13.56MHz tags), and LEDs that show visitors the system's state (see Figure 1). To allow flexible installation and easy relocation in exhibition spaces, the eXspot includes a rechargeable 1600mAh battery, making the unit portable. The RFID card, issued to visitors at the start of their museum visit, is designed with one side showing Exploratorium-related graphics and the other side a clear view of an RFID chip and external antenna to promote visitor curiosity.

Museum-based studies have demonstrated that some visitors view exhibit bookmarking as a desirable feature [1, 4]. The eXspot system enables visitors to capture information about exhibits they visit and take souvenir photographs while at the museum. Later, they can access the

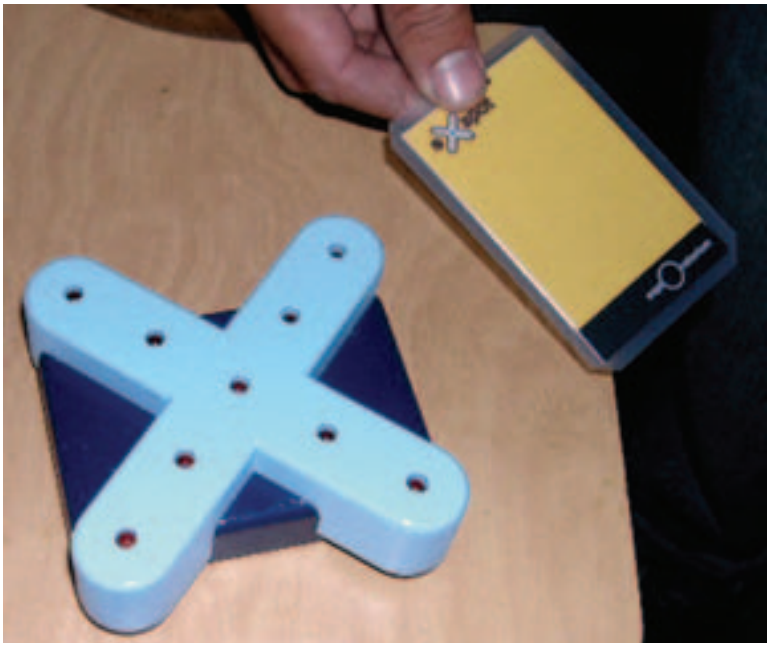


Figure 1. A museum visitor holds an RFID card (right) over an eXspot transceiver package (left) to bookmark an exhibit and activate a camera.

exhibit information on personalized Web pages. For example, by spraying water onto refrigerated glass at an Exploratorium exhibit, visitors cause ice crystals to form on the glass's surface. The crystals are then viewed through a polarized lens, revealing shapes and colors otherwise hidden to the naked eye. At another exhibit called the "Heat Camera," visitors see thermal images of themselves and get to explore the parts of their bodies that are hotter than others. eXspot RFID readers attached to the exhibits allow visitors to use their RFID cards to trigger cameras to take digital images of themselves, as well as to capture the thermal images or polarized ice crystal images from the exhibits.

The eXspot reader package constantly queries the environment for the presence of RF tags. When visitors approach the exhibit and hold their RFID cards in the vicinity of the package (within a few inches) the tag is read and its ID sent to a base station over the Mote radio. This communication takes the ID number of the card (as read by the eXspot reader), sending it wirelessly to a network base station where ID number, time, and exhibit information are recorded in a database of user visits. Although the card has a unique ID, visitors (at the start of their visit) enter their email address at a registration kiosk to register their cards. They do this in the interests of security, in case their cards are lost at the museum or on the way home, thus maintaining the privacy of their images and visit information.

After interacting with exhibits, visitors use their ID cards to log on to a museum kiosk and view the exhibit photographs they've captured, either of themselves or of the artifacts they've created (such as the ice crystal patterns). They can then continue their exploration—either from home or at the kiosks in the museum—by logging on to personalized Web pages through their ID card number and email address. While at their personal Web page, they view the dates they were at the museum, the exhibits they visited that day, and the photographs they took. The Web page also provides suggested links to additional online content and teaching materials (such as online exhibits, science articles, explanations, and home-based construction kits) related to the exhibits (see Figure 2). For a teacher taking students on a museum field trip, the Web page is useful after leaving the museum to support class discussion about the science experiments they conducted and how they relate to the science they are learning in class.

In addition to the Exploratorium, several other museums worldwide use RFID for visitor applications. For example, in 2001, the Museum of Science and Industry in Chicago opened a new 5,000-square-foot permanent exhibition called "Net-

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World" where visitors use RFID technology to learn about the Internet. First, they design personal avatars that are stored in the exhibition's network. Then, using their NetPass cards (with embedded RFID chips), the avatars accompany them throughout the exhibition, interacting with them as they learn about bits, packets, and bandwidth. With each new exhibit unit visited or during repeat visits later on, the network stores visitors' ID numbers and displays their avatars to help them through new experiences. To avoid issues of personal data privacy, no personally identifiable information is collected when the cards are issued.

Similarly, at the Vienna Museum of Technology, RFID has been used in an exhibition on the future of virtual reality to help blend visitors' physical and virtual experiences. Visitors purchase a card at an admissions desk, take it to a card-reader terminal, and create a personal profile that includes preferred language, favorite color, nicknames, and other low-security identifiers. The interaction metaphor represents a digital backpack for collecting multimedia clips. Visitors take their cards to any number of card-reader terminals throughout the museum.

The Museum of Natural History in Aarhus, Denmark, evolved its initial use of RFID from a collections management system to a visitor learning and interaction tool in an exhibit called "Flying," which includes stuffed birds tagged with RFID chips. Rather than depending on a curator scanning and tracking the specimens, visitors carry RF readers to actively scan tags attached to birds. Scanning a bird results in the presentation of associated text, quizzes, audio, and video to the visitor.

The Tech Museum in San Jose, CA, implemented RFID technologies in its 2004 "Genetics: Technology with a Twist" exhibition after experimenting with barcode readers and paper tags in earlier exhibits. Including the tags and readers in the cost of admission, the Tech gives visitors wristbands with embedded RF chips called TechTags (see Figure 3) that activate a variety of exhibits and trigger interactions with displays, including "Genetic Portraits" and "Address the Senate." RFID readers are tightly integrated into each exhibit, providing a constant power supply, as well as network connectivity. The museum also designed a virtual card-collecting game about genetics for its teenage visitors. By visiting specially marked genetics exhibits, visitors can collect and then view additional interactive Web applications (such as "Your Glowing Bacteria" and "Making Medicine") via a computer kiosk. Earlier this year, it launched the "NetP1@net Gallery" where visitors create personalized Web pages with photographs and images from their visits to the museum, then use their RFID numbers to retrieve the page anytime on the Web.

Figure 2. A visitor's personal eXspot Web page shows exhibits visited on a given day, photographs they captured at the "Heat Camera" exhibit, and additional online science resources, all of which can be viewed anytime on the Web.

Learning Experience

The RFID-enhanced interactive museum experiences discussed here illustrate early adoption of and interest by the museum community in using RFID technology to provide educational applications. Wireless RFID technologies are appealing to museums not only because of their relatively low cost compared to alternative technologies like barcode readers, but also because of their potential for improving each and every visitors' learning experience, as well as their personal sense of belonging to the museum community.

Museums invest significant human and financial resources in designing learning experiences in compelling, scientifically accurate exhibition spaces with interactive exhibits that aim to enlighten visitors about nature, history, art, and science. With the many permanent exhibits, floor demonstrations, and exhibitions, museums—especially science centers and halls of science—are often compared to an all-you-can-eat buffet with too many choices for the typical museum

visitor to sample.

At the Exploratorium, hundreds of interactive exhibits—covering everything from cells and microscope imaging to energy, motion, matter, and forces—are spread across 100,000 square feet of floor space. Most visitors, particularly children and school groups, see only a small subset of the exhibits on display. Typically, younger children pull the adults away from one exhibit toward any other exhibit before they have had a chance to digest the science behind the first exhibit. Museum researchers have documented the typical dwell time at exhibits as approximately 30 seconds [1, 3]. Rushing from exhibit to exhibit, visitors are unlikely to be able to fully explore the concepts, phenomena, history, or scientific relevance behind each exhibit in a single visit.

Figure 3. TechTags worn by visitors to The Tech Museum's "Address the Senate" exhibit. They first select a topic, then face the camera and give a speech to applauding dignitaries. The speech can then be played back.

A key aspect of learning in museums is how to deepen visitors' experience, extending it beyond a single visit. Leveraging technologies like RFID to bookmark visited exhibits, along with Web-based activities linking related exhibit concepts on Web pages, represents a way to learn about science beyond the museum setting and obviate the hurried-visitor problem.

As educational institutions, museums not only serve the public, they also aim to promote a stronger relationship with their members and communities. Using systems like eXspot as an embedded evaluation tool, Exploratorium staff stores and mines log files to study the nature of repeat visits to the museum, long-term use of RFID-enabled exhibits, and preferences for online content and learning activities of the visitor and member community. Because Exploratorium exhibits are in more than 100 museums worldwide, one can imagine multiple museums installing a uniform RFID tracking system, enabling the study of visitor behavior and preferences over extended periods across multiple exhibition spaces. Museum researchers can use this wealth of information to better understand visitor interests, assess informal science learning, and serve the needs of the public.

Public View of RFID

The most daunting barrier to adoption of RFID systems in museums is the visitors' own societal and educational expectations. Drawing from our

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evaluation of eXspot use trials, surveys, and conversations with visitors over the past three years, we have discovered that many visitors have erroneous ideas about RFID and little experience using RFID cards. Using RFID technology to make exhibits interactive or to collect content is not well understood by museum visitors. Although bookmarking is an established feature in art museum audio tours and on the Internet, museum visitors have a relatively undeveloped mental model of what RFID technologies are and how they work.

We've observed common visitor mistakes, including trying to quickly swipe the cards in front of a reader, waving the cards above a reader (out of range of the antenna), and placing the cards against the reader, then quickly removing them (before the ID is read). While we addressed some of these barriers to RFID use through visitor training and better shape design of the reader package, our experience points to the need for a common use metaphor for user adoption of RFID tags, cards, and readers in public spaces. We've considered metaphors comparing the use of the ID to a keycard unlocking an office door or a parking garage gate, a barcode being scanned at a retail store, and a credit card being swiped to pay at a grocery store.

Another barrier is visitors' existing conceptions about the technology and perceived risks to their personal data privacy, including being tracked or scanned remotely. In our evaluation of eXspot, some users believed the RFID card stored information from each exhibit visited, viewing the card as a mini writable disk drive. Because the museum does not store sensitive personal data or display it on visitors' personalized Web sites, and since a visitor-chosen login or email address is required (in addition to the card ID), a potential adversary trying to use a lost card to view personalized Web pages is relatively harmless. Furthermore, since the cards hold no personal data, electronically scanning or reading them yields only a hexadecimal ID number with no additional data.

In order to address problems of visitor expectations, more education inside and outside the Exploratorium is needed. We propose an approach that includes: a public display and docent demonstration explaining how to use RFID cards, how RFID works in practice, and why the chances of being scanned or tracked remotely are slim, as well as posting a privacy policy (on the Web and at visitor sign-in).

Conclusion

RFID technologies represent enormous promise for improved visitor learning in museums. Along with the convergence of smart cards, RFID, WiFi networks, and commercial transaction systems, the use of RFID technologies in museums is likely to expand, especially for creating new experiences and for extending learning beyond a museum's walls.

Despite the long history and track record of commercial RFID, going back to the 1960s, recent news coverage (concerning, say, Wal-Mart's plans to use RFID to track its inventory) and science fiction movies (such as *Minority Report*) featuring scanning technologies and ubiquitous information retrieval have shaped public perception of scanning technologies like RFID. Museums must educate their visitors about RFID and manage prevailing perceptions of the privacy risk to visitors, in addition to creating clever interactive exhibition designs.

Consumer education across all fields is necessary to help users hone their understanding of when and with whom to share their private information, as well as the associated risks. We are optimistic that technology design that addresses public concern about RFID and the perceived risk to personal data will enable the transformation of research prototypes like eXspot into everyday interactions at large-scale installations and public use in museums. C

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