RFID Technology: Implementation Possibilities in the Patron Experience

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INTRODUCTION

We see the increasing influence of technology on our everyday lives in the number of devices and systems that we use to communicate, stay organized, learn, and create. Technology not only connects people with each other and with information, but it also connects the many devices that we use to create a seamless network of information exchange. This network of everyday objects connected to each other by the Internet is referred to as the Internet of Things (IoT).[1] One focus of arts managers is to reach their audiences in clearer, broader, and more efficient ways. Technology, specifically IoT, is a tool to achieve this aim. The following research provides a view into RFID technology and opportunities for its use in the visual arts.

The origin of IoT revolves around a coffee pot in a computer lab at the University of Cambridge when the Internet was still in its early stages. The story explains IoT quite well: this particular coffee pot was shared among several computer researchers at the university who often traversed several flights of stairs to find an empty pot. To fix this problem they used a video camera, a frame grabbing card, and computer software to create the Trojan Coffee pot server, which enabled each viewer to see an icon-sized image of the pot on their computer screens and assess if the coffee pot was full before making their trek to the break room. This simple story clearly explains a useful solution that required an everyday object to contain embedded technology. The main goal of IoT is to detect the environment, gather data, and communicate with the physical world.[2] The future of IoT is growing very quickly; some estimate that in five years the number of connected objects will outnumber the people on the planet.[3] RFID (Radio Frequency Identification) is a specific technology involved in IoT that can be embedded in objects and that has transformed industry, business, and education. This research will explore how RFID technology can be used by visual arts organizations in the patron experience by describing the technology, its potential uses in museums, and obstacles to these uses.

What is RFID?

Radio Frequency Identification (RFID) is a technology that uses radio waves to transmit information in order to identify people or objects. An RFID system is made up of three parts: an antenna, a reading device (reader or scanner), and a microchip. Usually an RFID tag or transponder is comprised of a microchip attached to an antenna. An RFID reader transmits radio frequencies, which wake up or power the microchip's circuits on the RFID tag, enabling it to operate. The microchip modulates those frequency waves and sends them back to the reader, which in turn converts the information into digital data that can be translated by a computer.

The technology from which RFID was developed was originally used by the British air force in World War II to distinguish between enemy and friendly aircrafts. Radar was already in use to detect airplanes, but it could not distinguish between them. The British developed an Identify Friend or Foe (IFF) system which became the model for current RFID technology.[4]

Classification

RFID tags are broadly classified as passive or active and read-only or read-write depending on their chip's capability. Passive tags have no onboard battery and are powered by the energy from the reader as described above. Because passive tags do not contain an internal power source, they are quite small and often as thin as a few sheets of paper. These tags are used for access control, race timing, and asset tracking. Active tags are powered by batteries housed on the tags themselves enabling them to broadcast their own signal, and therefore do not need to be powered by the reader. These tags are usually larger than passive tags and they are often

1   Durand et al., "Middleware for the Internet of Things: Principles," 185-186.

2   Kim et al., "RFID Adaptor for Detecting and Handling Data/ Events in Internet of Things," 140-148.

3   Gallagher, "The Future is the Internet of Things, Deal With It," Ars Technica, October 25, 2015.

4   Prabhu, Design and Construction of an RFID-enabled Infrastructure: The Next Avatar of the Internet, 21.

used for several years. They may be housed inside a protective plastic shell. The two types of active tags are transponders, which only communicate when interrogated by a reader, and beacons, which periodically transmit their identifying information. Active tags are used in high-speed environments like highway tollbooths and for tracking goods from a long distance, such as containers on a railroad

Figure 1: Active RFID Tag – E-Z Pass toll payment Source: Mikeettm used under CC BY

Figure 2: Passive RFID Tag – marathon race chip. Source: Yoppy used under CC BY
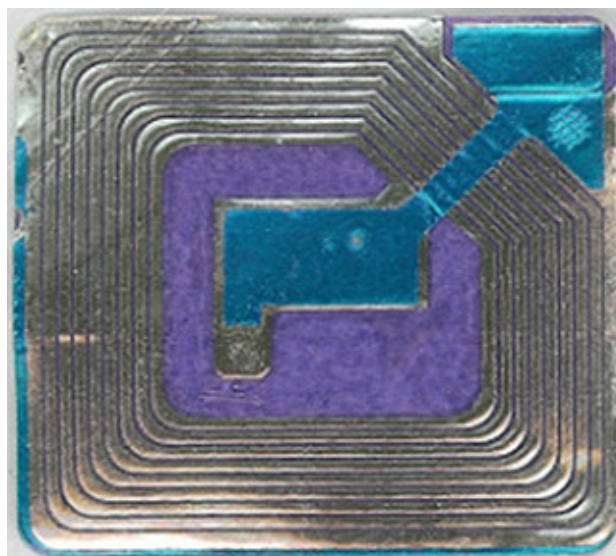

Figure 3: RFID Tag - Source: midnightcomm used under CC BY

car.[5] Read-only tags have a serial number stored on them during the manufacturing process and no new information can be added. While the serial number cannot be altered on read-write chips, additional information can be added to the chip describing the product to which the tag is attached. The latter type is commonly used for tagging objects for storage in museums.

RFID vs. Barcodes

Since the passive, read-only type of RFID tags can only read the information stored on the tag and cannot update it, one might wonder why RFID should be used instead of barcodes. While there will still be a use for barcodes in some industries, there are many advantages to RFID. Each tagged product or person has a unique identification code that contains information specific to that tag. Think about the barcode on your pomegranate Greek yogurt – that barcode is the same one on all the pomegranate Greek yogurts made by that manufacturer, but without a unique identifier, you won't know which one will expire first. Another advantage is that RFID tags function without the tag needing to be visible. A barcode reader needs a clear path to the barcode in order to read it, taking more time to scan. Barcodes must also be placed on the outside of an item increasing wear and tear. An RFID tag can be read[6] from varying distances quickly and can be enclosed in plastic making it durable.

Hardware Options for Museums

The hardware needed for an RFID system includes readers, tags, and a server. A sample system might include a reader, mounted to each exhibit that will have connectivity options and interactive capability, and tags that are distributed to visitors and either worn like lanyards or bracelets, or carried like a card or a token.

There are three types of frequency systems available: low frequency (LF), high frequency (HF), and ultra-high frequency (UHF). The differences in

5   Thrasher, "Active RFID vs. Passive RFID: What's the Difference?" RFID Insider: Tracking the RFID Industry, June 20, 2013.

6   http://www.technovelgy.com/ct/Technology-Article.asp?ArtNum=60

the various systems include sensitivity to radio wave interference and reading range, which is how close the tag must be to the reader to transmit information. The parameters of the read ranges are 10 cm for LF, 10 cm – 1 m for HF, and up to 12 meters for UHF.

Readers
The three general types of readers used in a museum are fixed, handheld, and portals.

• Fixed readers are the readers that are attached to objects or exhibits that track visitors' movements and display information about the exhibit when an RFID tag is read,.
• Handheld readers are used when staff must "scan" a tag for access control. A handheld reader could also be mounted and visitors could scan their own tags to display information or to "check-in" at a particular location in the museum. The Drents Museum in the Netherlands uses RFID technology to track visitors' routes throughout the museum helping the museum to identify the most popular exhibits. The museum also offers kiosks where visitors can scan their cards to look up more detailed information about a particular artifact.
• Portals are walk-through readers where patrons can scan their tags as they enter or exit specific areas or the museum entrance. When speed is important, a portal structure may be preferred over a handheld reader

Tags
As mentioned earlier, tags can be active or passive, and either be read-write or read-only capable. Aside from those determiners, the size, medium, and functionality options of a tag are boundless. RFID tags can be embedded in plastic cards, sealed inside wearable bracelets, affixed between a plastic and a laminate to create a sticker, or even inside a paper ticket. RFID tags are more robust than barcodes; they can withstand much harsher environments including extreme temperature, moisture, and wear. What form the tag takes is a decision a museum must make based on factors of reusability, durability and wear-ability while at the museum.

Server
I mention servers in the hardware section because while cloud-based options provide access from anywhere, they are often much more expensive than physical servers. A server is necessary to store the information coming from the tags, to track the tag activity, and to store the database that holds the exhibit information. Museums might have a database of objects and artifacts that is designed for use with RFID software if they are already using this technology for security and inventory tracking. Museums also likely have a CRM (Customer Relationship Management) system for member, donor, and ticketing information.

Software Options
Popular Customer Relationship Management (CRM) systems used by arts organizations include Salesforce and Tessitura (interested readers can read further on the subject in the 2015 Ticketing and CRM software survey). The value of a CRM system is realized when it is used to derive meaningful data, such as showing the path of a patron's visit including how much time he spent at each exhibit. Even in a simple example one can see how meaningful that information would be to a museum to find out where patrons are spending their time and what interests them the most. A follow-up survey or customized communication stream would benefit an organization's audience development and donation efforts. The RFID software options are numerous, but many simply perform a function such as tracking scans, creating inventory lists, and time-stamping specific activities. Many companies that produce tags and readers also sell and offer support for the software to use the system including the compatible APIs (Application Programming Interface) to connect with databases and user interfaces necessary for end users to operate the system.

RFID IN MUSEUMS

RFID has many applications that are relevant for museums including collection management, access control (for both exhibits and visitors), interactive and educational applications, and cashless payment

systems. Often visitors are overwhelmed by the vast amount of information aimed at them from exhibits, museum literature, and audio tour guides. Current uses of RFID technology in museums pertaining to user experience include personalized solutions to enhance and streamline visitors' museum experiences. Some advantages to these systems are their feasibility, efficiency, and low cost.[7] RFID personalized solutions are more efficient compared to solutions involving human museum docents or tour guides. The cost of an RFID system depends on many factors: the application, the size of the installation, and the type of system needed. Passive tags, which are probably the most widely used in museums, range from $0.07-0.15 in their simplest form.[8] The packaging of the tag (wristband, paper ticket, or card) will raise the price depending on the materials needed, but buying in bulk can reduce the price. Readers range in price from $500 to $2,000, but it all depends on the type of reader needed. Other costs include integration software and deployment services. As more consumers use RFID technology, the price continues to drop, making these benefits even more attractive.

Interactive Exploration

RFID-enhanced user experiences occur in a few different ways. The exhibitions can be tagged and the visitor carries a reader, either a personal enabled smartphone or a device provided by the museum. This approach requires that the visitor scans the tag, while multimedia content is displayed on the reader or an application about an artifact or exhibit is launched. The reverse method is also possible: visitors are tagged either by carrying a card or wearing a wristband or badge issued by the museum at the point of entry. These wearable RFID tags may be used as tickets for entrance into an exhibit. In this case the readers are mounted on exhibits and read the visitor tags as they come within a certain distance. This action starts up an active exhibit, perhaps with lights or moving parts, displays information about the exhibit, or even takes a picture with cameras triggered by the

reader. The visitor can take the RFID tags home and access additional information by entering the tag's unique identification code in an application on the museum's website, thus continuing the educational process and providing data for the museum's use.

RFID Cashless Payments

Paying with RFID is faster and more secure than traditional methods. The speed of an RFID or cashless transaction is about 10 seconds faster than a credit card purchase and about twice as fast as a cash transaction. The transactions are highly encrypted and the type of data transmitted is not sensitive information like account numbers, but rather transaction numbers. This makes the transactions secure. Additionally, in the case of an Internet outage, it is possible for vendors to complete transactions without Internet, unlike credit card transactions. This advantage makes sales possible all of the time.[9] Many music festivals around the world use RFID cashless systems to make the festival experience stress-free and safe for their patrons. One example is TomorrowLand in Belgium, the largest electronic music festival in the world that sold out with over 180,000 patrons in 2015. For several years they have employed an RFID system for access control, and in 2015 they introduced a cashless payment system to their vendors and patrons. The results, according to Intellitix, the festival's RFID technology provider, were increased revenues and decreased costs for the event organizers. Other advantages include decreased theft, increased spending, and the elimination of falsified numbers.

Management of Collections

Tagging artifacts and exhibitions makes the inventory of objects, loans to other museums, and even the movement of exhibits within a museum efficient and error-free. With hand scanners, curators can scan artifacts as they check them in and out of a location. Alternatively, an RFID reader gate (like a portal mentioned earlier) can track the movement of an exhibition and save the information with details in a database. Inventory identification and loan processes are six to ten times faster with RFID than with barcodes.[10]

7 Karimi et al., "RFID-Enhanced Museum for Interactive Experience," In Multimedia for Cultural Heritage, 192-205.

8 RFID Journal, "Frequently Asked Questions."

9 Technovelgy.com, "What is RFID?"

10 Hadatap, "Systems for Museums."

Protection of Collections

Access control functions of RFID systems, a very common use in museums, can ensure that the right person has the clearance to enter a secure area and to move artifacts or exhibits. If an invalid scan is read, the system can alert security. Camera technology can also be integrated with the RFID system for additional security measures. Recording storage and transportation conditions in real-time allows for ideal exhibition monitoring and protect against damage.

RFID IN MUSEUMS

The following case studies are only three examples of how RFID technology is being used in different types of museums: an interactive science museum, an aquarium, and a visual art museum. The dates of use demonstrate that this technology is not new, but is being utilized in new ways with new advantages and discoveries.

Exploratorium, San Francisco

The Exploratorium, an interactive science museum in San Francisco, employs a "custom designed RFID application called eXspot." RFID tags are embedded in cards that patrons register at kiosks at the entrance of the museum. They enter their names and email addresses, not only for security in case they lose them, but for the museum to collect patron information, and for personalization on their interactive experience. They then carry the cards with them on their visit. RFID readers are mounted on various exhibits throughout the museum and read tags that come within a close proximity. As they explore the museum patrons can bookmark exhibits they find particularly interesting and then access more information on a personalized webpage using the card's unique ID through the museum website. There are cameras mounted on several exhibits that are triggered by visitors' RFID tags to take pictures of the patron or of an experiment they performed or an artifact they created. These photos are also available upon logging in with the card ID number.[11]

11 Hsi and Fait, "RFID Enhances Visitors' Museum Experience at the Exploratorium," Communications of the ACM, 60-62.

Figure 4: Exploratorium's Main Floor, San Francisco. Source: Amy Snyder used under CC BY.

Underwater World, Singapore

"Gone are the days when visitors are happy looking at animals and matching them with the information on the sign boards," said Peter Chew, Underwater World's Sales and Marketing Director. Singapore's largest oceanic park adopted RFID technology in 2007 by tagging fish in their "Living Fossils" aquarium to identify and track them better and also so that visitors could learn more about them.[12] It was the first aquarium to use RFID technology in this way. The tags were imbedded in seven species of these rare fish and when they swim by RFID readers on the outside of the tank where visitors are observing, information about the fish is displayed on a touch-screen display. Visitors can use the touch-screen computers to find out about each species' name, diet and, characteristics.[13] Visitors can also adopt toy fish, name them, and save the information to the museum's database. When a visitor's fish is placed near a reader, the name of the toy pet and its information is displayed. Since 2007, many aquariums have begun using RFID technology both for educational and informative purposes and for interactive and "citizen scientist" opportunities as well.

Ambrosiana Art Gallery, Italy

The Ambrosiana Art Gallery in Milan boasts "more than 1,400 sketches, drawings, and masterpieces created by Leonardo da Vinci."[14] In October 2012, the museum introduced RFID technology with the use of RFID-enabled smartphones as a means of describing the works and also providing an audio guide. Guests can use their own phones or borrow one from the museum and as they learn about the art, and they can use their phone to save a list of particular works they enjoy in order to find the prints for sale in the museum's store. In the Ambrosiana, the RFID tags are affixed to the walls above each work's description. The tag's info is deciphered by an NFC (Near-Field Communication,

a type of RFID) Museum App designed for the Ambrosiana installed on the smartphone. Mobile People, the Italian technology company who designed this system for the Ambrosiana, used RFID technology for ticketing and exhibitions in this year's 2015 Milan Expo.

Lessons from these Studies

The uses of RFID systems in these museums show a few potential uses of this technology. It seems most advantageous for visitors to carry a personalized RFID tag that can be attached to their email address for future contact and that can track their journey throughout the museum for audience data analysis. Visitors that take home their tags and log in to find out additional information continue the educational process and also keep the museum experience alive in their minds. The Underwater World exhibit provides visitor interaction along with education as part of its user experience. Interactive learning is a natural by-product of the growth of digital technology and RFID technology provides creative options for museums. The ability to listen to an audio guide and simultaneously save images to one's own device through the museum's app is a beneficial advantage for the Ambrosia Museum and its innovative programming. All of these RFID uses bring the patron closer to the art and make a deeper connection with the art possible.

Unmet Potential Uses

RFID cashless payment systems are another possible use for museums. According to the Association of Art Museum Directors "Art Museums By The Numbers 2014," the average museum visitor spends less than $8.00 per museum visit including the cost of admission and any spending at museum shops and restaurants. RFID companies boast that cashless payment systems increase spending by 15-30% per person. The 2012 PayPass Adoption Study by MasterCard showed a 30% increase in consumer spending during the first twelve months of owning a Mastercard PayPass card which uses RFID technology.[15]

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12 Tan, "Underwater World Singapore," Singapore Infopedia, 2011.

13 Jones, "RFID Provides Interactive Experience at Living Fossils Exhibit," Information Week, May 29, 2007.

14 Swedberg, "Milanese Art Museum Uses RFID to Attract a Younger Audience," RFID Journal, December 3, 2012.

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15 Heun, "Research Doesn't Pinpoint Reason, But Study Finds PayPass Cardholders Spend More," Payment Source, April 26, 2012.

Obstacles to Museum Use

Sherry Hsi and Holly Fait, researchers at San Francisco's Exploratorium have found that "the most daunting barrier to the adoption of RFID systems in museums is the visitors' own societal and educational expectations."[16] Many individuals have
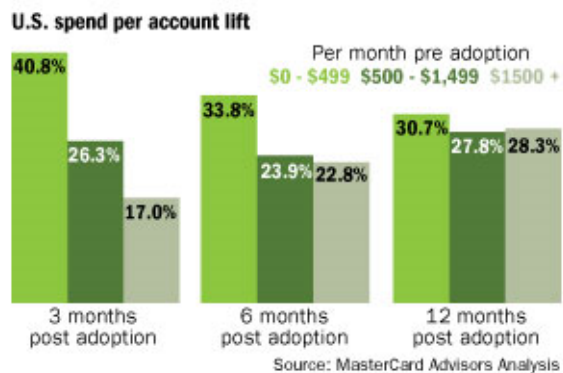

Figure 5: U.S. Spend per Account Lift

false ideas about RFID technology and they have little or no experience using it. Festival organizers at large music events that use RFID access control systems have found that the first day of an event is about the education of the patron. Many patrons erroneously attempt to swipe their RFID wristband around the reader zone too quickly not getting an accurate read or wave it from too far away and are not in range of the antenna. By the second day of a festival, many of these problems are completely solved because the patron understands the process. Another barrier some patrons have is a misunderstanding of the technology. Many visitors fear that their personal data is at risk and are afraid of being tracked remotely. Although museums do not have personal information stored on their

16 Hsi and Fait, "RFID Enhances Visitors' Museum Experience at the Exploratorium," Communications of the ACM, 64.

patron RFID tags, educating patrons on this matter is necessary to enhance the visitor experience.

CONCLUSION

There are enormous possibilities for the use of RFID technology in museums to enhance the visitors' experience. Interactive learning from RFID-enabled exhibits, as well as the ability for the patrons to continue the educational process after they leave the museum, are valuable benefits. Positive user experiences might also increase repeat visits to museums that implement this technology. When a museum is able to collect data based on a visitor's exhibit preferences and activities, it can personalize invitations to future exhibits and promote more interactions with the visitor. This level of personalization can lead to more informed exhibit choices and increased attendance. With educational opportunities, cashless transactions and integrated ticketing systems, RFID technology can increase the efficiency and educational reach of a museum.

"The number one benefit of information technology is that it empowers people to do what they want to do. It lets people be creative. It lets people be productive. It lets people learn things they didn't think they could learn before, and so in a sense it is all about potential."

-Steve Ballmer, former CEO of Microsoft

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