# RFID Localization for Tangible and Embodied Multi-User Interaction with Museum Exhibits

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## ABSTRACT
RFID is usually used for *identification* but with some post-processing it can also be used for *localization*. These properties expand the typical range of possible interactions with digital displays in museums. Our goal is to encourage the collaborative investigation of a rich information space presented on an Ambient Display in a museum exhibit. We consider two different models of interacting with an exhibit: *Tangible Control,* wherein passive RFID tags are embedded in some artifacts and multiple users can control the information on the screen by moving those artifacts, and *Embodied Control*, wherein people directly carry an RFID tag and interact with the information by walking within the simulation space. Each model has different implications for how the visitors might relate (a) to the information being displayed, and (b) to one another. Here we present preliminary results on the suitability of a single-reader and passive tag setup for providing localization input.

**Author Keywords** Human-Data Interaction, Embodied User Interface, Tangible User Interface, Ambient Display, Informal Learning Environments

**ACM Classification Keywords** H.5.2 [Information Interfaces and Presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

**General Terms** Design, Human Factors.

## INTRODUCTION
Over the past two decades, there has been an increased interest in how museum exhibits might promote interactive learning and sociability [6], spawning new forms of interactive experiences like large shared ambient displays. Prior ambient display research has looked into using RFID technology to *identify* users (an example is the UBWALL [5]). A few systems have combined both *identification* and *location awareness*, like an ultrasonic method used with handhelds in art museums [2], and the Hello.Wall [3], where one long-range and one short-range RFID reader are used to define three distance zones from a display. Our technological approach is similar to Hello.Wall, but we have striven to keep technology costs down by using only one reader and inexpensive passive RFID tags. Our interaction design approach is distinct from prior work: proximity is not just used as a lure to encourage users to approach, but is used to directly control interaction with the display's data.


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## SCENARIO
Our system prototype is a combination of a shared projected display, a single RFID reader and individual passive RFID tags. The shared display shows historical maps about immigration flows to the United States during various eras, drawing on the NEH-funded *GIS for History* project [4]. We consider two different approaches to the users' interaction: *Tangible Control,* where country-of-origin data is associated with an artifact; and *Embodied Control,* where country-of-origin data is associated with the person carrying the tag. We expect that visitors will respond very differently to these two interactions strategies and will consequently show very different interaction patterns, both when exploring the data in the exhibit and with each other. Future work will explore these usability issues; here we report on the work done to implement the system.

## DEVELOPING THE PROTOTYPE SYSTEM
The system can *identify* each tag from its Electronic Product Code (EPC). To *localize* the transponder, we use the Received Signal Strength Indicator (RSSI) and adopt a *location fingerprinting* method similar to [1], except our approach uses a single reader and builds Gaussian distribution for each location, as opposed to using multiple readers to triangulate. Our technique is divided into two phases: the *Training Phase* and the *On-Line Phase*. During the *Training Phase*, we conducted multiple trials placing several tags at 4 different proximities from the reader and recording the RSSI as training data (Figure 1).

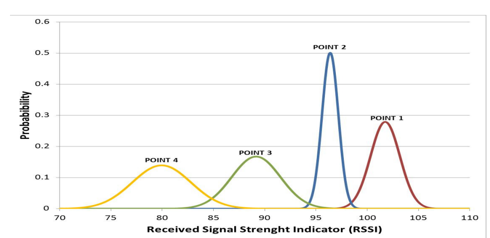



**Figure 1. Four Gaussian probability density functions corresponding to 4 points (25 cm, 50 cm, 75 cm, and 135 cm) given the signal strength returned from a tag (x-axis).**

The *On-Line Phase* relies on these Gaussian distributions, as they model the probability of being at one of four points, given the RSSI. For instance, we can compute the value of

G1($p$), where G1 is the probability density function of the Gaussian distribution for point 1, while $p$ is the value of the RSSI received back from a tag placed at an unknown location. If the value of G1($p$) is greater than a threshold, we assume that the tag is near point 1.

### Tangible Control and Embodied Control

With *Tangible Control,* we used three photo frames with immigrants pictures to represent Italy, Ireland and Mexico (Figure 2a). Each frame is tagged with an ISO 18000-6C transponder and placed on a table. Multiple users can interact with the screen by moving one frame to be closer to or farther from the shared display. At the beginning, a blank map of the United States is projected on the shared screen. Users can retrieve the immigration data from a specific country by placing the artifact that represents that country on the table. When a tagged object is *identified*, scaled centroids are displayed on the map, representing the size and location of immigrant populations corresponding to that country. If more than one frame is on the table, the system recognizes their mutual position, and re-arranges the visualization to prioritize those nearer to the screen. With *Embodied Control*, each person receives a tag, which can be linked with one (or more) country of origin. We marked four different points on the ground. The system can *identify* and *localize* the RFID tags as in the *Tangible Control* approach; what makes the difference is that each person *becomes the object* of her/his own interaction, as the screen is directly controlled by people's movements within the simulation space (Figure 2b). *Embodied Control* still poses some technical challenges that should be explored in future work: we must consider how tall a person is, the way she/he carries her/his tag and the speed she/he moves.

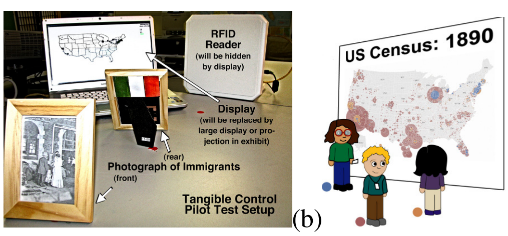
(a)  (b)


**Figure 2. (a) Tangible Control (b) Embodied Control**

## PRELIMINARY SYSTEM EVALUATION

To evaluate the system, we used the Thingmagic Astra reader and three Alien 9634 tags. We set the power level of the reader at 30dBm and we performed one read operation every 50ms. Under static conditions, when the user does not move the tags, we measured the *refresh rate*, that is the time between two consecutive successful reads of a tag (i.e. the tag is both identified and localized). The results of a 20 minute test shows a mean of 2.00 seconds (SD=0.05), with a minimum of 1.62s and a maximum of 2.43s. Under dynamic conditions, when the user moves a tag, we evaluated the *response time*, defined as the time elapsed before the system interprets that a tag has been moved from one zone to another. We registered a mean of 2.00 seconds (SD = 1.47), with a minimum of 1s and a maximum of 10s. Larger values seem to be due to temporary occlusions by the human body and manufacturing inconsistency across (supposedly identical) tags.

Given these findings, our design recommendations for using inexpensive passive tags to interact with a shared screen are: (1) the system cannot be instantaneously aware when a tag exits the reader area; if the time-out is too low, a tag could intermittently appear and disappear, just because the refresh rate is not fast enough. Indeed, the time-out should be greater than the average *refresh rate* - thus we recommend performing a user study to determine, for a specific context, which is the greatest time-out that the users can tolerate. (2) The system is not immediately stable after a tag is moved. Although the localization stabilizes after a few seconds, this lag can be misleading to users. We recommend not updating the shared display before the average *response time*; furthermore, some scenarios may demand the adoption of a trajectory-sensitive algorithm for driving the display. (3) We observed a user tendency to line tags up perpendicular to the display. We thus recommend incorporating visual cues in the physical interaction space, as the RSSI changes within a radial, not linear, pattern.

## CONCLUSION AND FUTURE WORK

This work proposes two approaches (*Tangible Control* and *Embodied Control*) to interact with an ambient display using RFID. We also illustrated some limitations of using inexpensive passive tags for this purpose. We are currently evaluating the adoption of semi-passive tags to achieve a smoother level of interaction and to extend the scope of the reader interrogation area. We are also planning an experimental user study, under both the *Tangible Control* and *Embodied Control* approaches, to evaluate how people respond to these two different interactions strategies.

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