A Study of an Augmented Museum Experience

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This paper describes the design of a study of visitors to a science museum who are equipped with wirelessly connected handheld devices. The museum exhibits are augmented with information and services in the form of web pages, and the users can access those pages conveniently when in the proximity of the exhibits as well as from their desktops outside the museum. The goal of the study is to examine use of technologies for 'bridging the physical and virtual worlds'. We describe the museum setting and the technologies deployed. We outline a layered model for describing the user's activities and a methodology that we propose for our analysis. We explain how the notion of combined virtual and physical navigation is central to the study, which we have just begun.

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Abstract. This paper describes the design of a study of visitors to a science museum who are equipped with wirelessly connected handheld devices. The museum exhibits are augmented with information and services in the form of web pages, and the users can access those pages conveniently when in the proximity of the exhibits as well as from their desktops outside the museum. The goal of the study is to examine use of technologies for 'bridging the physical and virtual worlds'. We describe the museum setting and the technologies deployed. We outline a layered model for describing the user's activities and a methodology that we propose for our analysis. We explain how the notion of combined virtual and physical navigation is central to the study, which we have just begun.

1 Introduction

Newly emerging portable device and wireless network technologies have the potential to significantly enhance the experience of a visit to a museum. On the exhibit floor, visitors carrying wirelessly connected devices can be given opportunities for exploration, sharing, explanations, context, background, analytical tools, and suggestions for related experiences. In addition, conventional desktop and Internet technologies can help extend the visit: in advance, through activities that orient visitors, and afterward, through opportunities to reflect and explore related ideas.

This paper reports on the design of a study of users equipped with such technologies, a study which has just begun at the Exploratorium science museum [7]. The project investigates how a web-based computing infrastructure can provide museum visitors with an augmented museum experience so that they can better plan their visit, get the most out of it while they are in the museum, and be able to refer back to their visit once they have returned to their home or classroom. The goal is to understand how different aspects of the technologies, and the content delivered through them, affects engagement with the exhibits and other educational materials, and affects learning activities.

The exhibit environment in interactive science museums provides the public with direct experiences with scientific phenomena and ideas. But while the exhibits provide opportunities to stimulate inquiry and exploration, they are not, by themselves, as successful as they might be in supporting conceptual learning, inquiry-skill building, analytic experiences, or follow-up activities at home or school. An ideal learning experience with exhibits would include ways of capturing the experience for later reflection, being able to access additional material that is providing a context for the exhibit, and extending the interaction with the exhibit beyond simple observation and direct physical manipulation. If science museums are to fulfill their potential role as multi-dimensional educational institutions, they need techniques that support these needs. And those techniques need to augment the simple exhibit experience without destroying the informal ambiance that is the hallmark of museums.

We augment the museum environment with technologies developed by the CoolTown research program at HP Labs [9,10]. In CoolTown, all physical entities (people, places and things) have 'web presence'. Nomadic users navigate from the physical to the virtual world by picking up links to web resources using a variety of sensing technologies such as infrared receivers and barcode readers. Those readers are integrated with their handheld device, which is typically wirelessly networked. Users access electronic services by using their sensors to pick up URLs from barcodes or infrared 'beacons' attached on or near the objects of

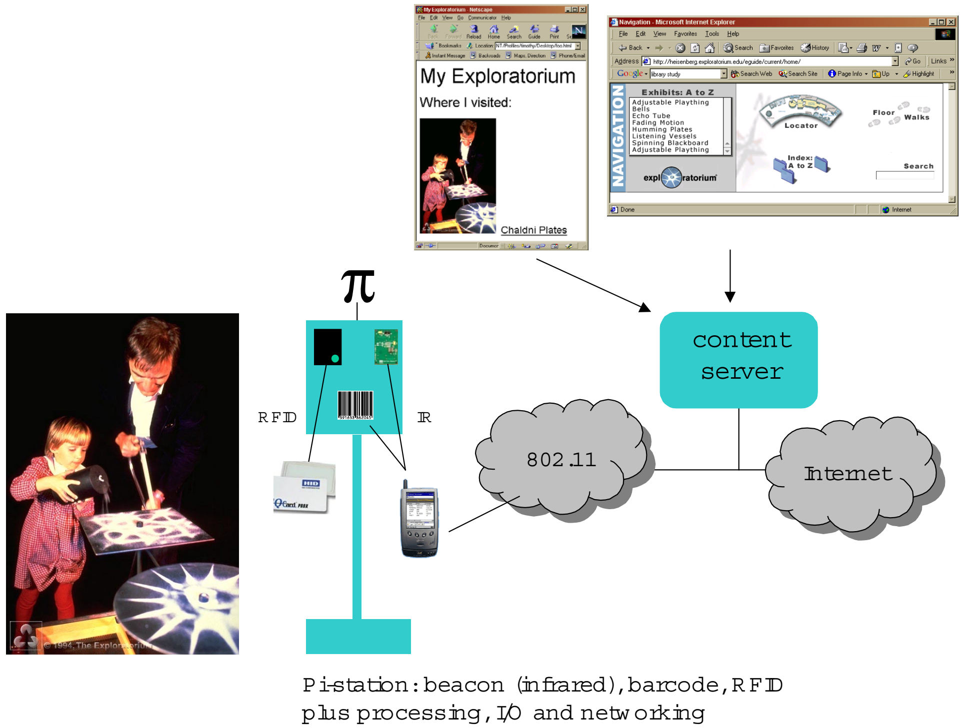

Fig. 1. The augmented museum.

interest. Those services are provided using ubiquitous web technology: web browsers on the handheld device and web servers in the environment. The services can be adapted for users based on their context, e.g. their identity, location, device capabilities, personal interests and preferences.

The Exploratorium user study has three specific goals:

1. To study use of CoolTown technologies: the uses to which users put them; the difficulty or facility with which they do so. Our intention is to build models of use in situations where people move between physical and online content during regular activities.
2. To apply these models to understand the effects of the technologies and the content delivered through them on the user's 'engagement' with the exhibits and with other materials provided by the Exploratorium.
3. Through our experiences in the domain of science museums, to develop models and methodology for studying users in mobile computing environments, for use in future pilot programs and other mobile computing domains.

1.1 Overview of the augmented museum

The augmented museum consists (see Figure 1) of the physical and virtual artifacts provided by the Exploratorium and the system we have developed for linking them:

Exploratorium artifacts:

- the exhibits, which vary greatly in their construction but are thematically arranged few feet apart throughout the museum;
- web pages giving information about the exhibits and related topics, and services for user-user communication or even interaction with the exhibits themselves;

Fig. 2. Handheld devices. Left to right: HP Jornada 548; HP Jornada 690; Hitachi ePlate.

- customized ‘myExploratorium’ or ‘ourExploratorium’ web pages, which document the visit or visits by a particular user or group. Those pages contain whatever users have chosen to record about their visit, such as saved bookmarks to web pages, a map of their physical path through the museum, annotations about exhibits or web pages, and photographs.

System components for linking the physical and virtual artifacts:

- ‘pi-stations’ (‘pi’ = ‘point-of-information’) stations next to the exhibits, which enable the user to capture exhibit-related web pages;
- handheld devices with web browsers that the users carry while in the museum;
- an 802.11 wireless LAN which connects the users’ devices to local services and the rest of the Internet;
- content servers for storing user data and web pages, and for presenting customized pages by combining user data and content templates;
- standard PCs and web browsers, used to access the museum’s pages while outside its walls.

Here is one potential scenario of MyExploratorium system use. Before a visit, a ninth grade class and their teacher prepare at school. They construct personalized web pages on which class members type questions they would like to answer and the teacher suggests exhibits to visit and questions that she would like them to answer. At the museum, the children are assigned handheld devices which they use to pick up their own pages and the Exploratorium’s pages at the exhibit. They save links to the exhibits that most interest them; they make short notes about the questions they had and about new questions that arise during the visit. They use the cameras mounted on the pi-stations to photograph exhibit phenomena; those images are saved to their personal pages. They also communicate with one another using a bulletin board system. When they return to school, the children can use the Web to review the tour they took through the museum and the notes, images and bookmarks to exhibit pages that they recorded at the time. They discuss and show one another their shared experiences and work together on answering the questions that they and their teacher have raised.

2 System Requirements and Technologies Used

In designing our system we started with the following assumptions:

Users. The system users are a diverse group, covering a large range of ages, levels of scientific sophistication and familiarity with computers and handheld devices. We would like to provide personalization and user control of the information and services through customization at the levels of an individual or a group. The system should also support communication between visitors.

Content delivery. The system needs to support both synchronous delivery of content to handhelds at the exhibit and asynchronous delivery for users who may not want to absorb a large amount of information on the spot but prefer to ‘bookmark’ interesting artifacts and browse the web pages later.

Practical considerations. There are issues as to how users can carry and use handheld devices, and how well the devices will survive in a somewhat hostile environment. The physical environment is noisy and bustling. Many of the exhibits involve whole-body physical action (e.g. spinning around on turntables or chasing balls across the exhibit area) and/or manipulation using both hands.

We aim to compare the physical affordances of various technologies and thus decided that we would exploit the following in our study:

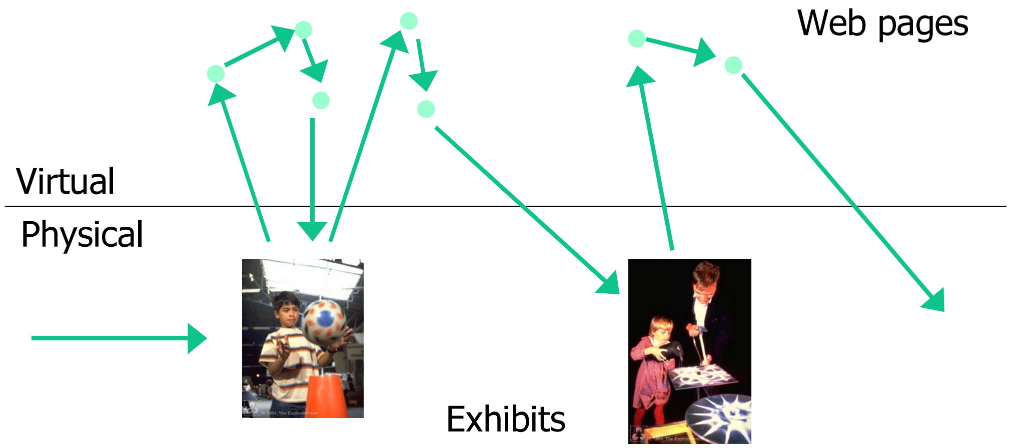

Fig. 3. Physical and virtual navigation interleaved.

Identification: for identifying exhibits, we use CoolTown beacons [5], barcodes and radio-frequency identification (RFID) readers placed near the exhibits; correspondingly, users have infrared receivers, barcode readers and RFID tags [14]. RFID tags are attached to the handheld devices; they are worn as wristbands or badges by users who do not carry those devices. Users use their RFID tags to 'remember' an exhibit, which they can view from their myExploratorium page later; they use barcodes and beacons when they want to view pages on the spot.

Handheld devices: Users may carry HP's Jornadas 548 and 690 or a Hitachi ePlate (see Figure 2), each with a wireless connection; or, they simply carry an RFID tag. These represent a range of physical form factors (weights, screen sizes) and input technologies (stencil, keyboard, audio). All devices render in color. The ratios of physical sizes and screen sizes is roughly 1:2:4.

Pi-stations. Pi-stations are portable and modular information points that stand next to the exhibits. They serve to identify the exhibit's web content: each provides a beacon, barcode and RFID reader so that we can test all modalities. They provide some processing power and a wireless network connection to the rest of the infrastructure, so that we may provide interaction with the users. Pi-stations can be equipped with a camera, screen and audio I/O.

Web infrastructure. The CoolTown Web Presence Manager [6] delivers personalized content. It combines recorded information into personalized web pages that can be accessed from any device with a standard browser. We also utilize standard web servers for the externally available content and we have developed a web proxy through which all traffic from the handheld devices passes. With the user's consent, we can conveniently log all web activity from their device.

Content. The content is all web-based. It includes text, images, audio and video. We include pages for text input so that users can take notes, answer questions or communicate on a bulletin board shared by a designated audience – e.g. anyone in a particular group, or anyone visiting the Exploratorium.

3 Models and Methodology

The objective of our study is to evaluate dependencies between the user's experience and the technologies used, including their modes of use and deployment. The core of this research is development of models for understanding the impact of the technology on user behavior, as well as development of a methodology to measure this impact and to reason about higher-order effects such as informal learning.

Our augmentation of the museum has a potential to enhance the learning process and especially to benefit the explanatory and generalization stages. But it introduces a novel dimension of *navigation between the physical and virtual* to browse artifacts and the effects of switching the user's attention between the two is an important component of the model.

We have chosen to separate our model into several levels of description:

1. **Basic affordances** – a model of the handheld devices, the wireless network and the identification technologies as they impinge upon the activities and effects that the system is designed to support. Examples of these affordances are the handheld devices' physical tractability (or lack of it), screen properties and input modes; the tendency of wireless connectivity to break up in certain areas; the 1-2 meter distance from which a user can receive a URL from a beacon, versus the 1-10 cm range from which the user scans a barcode.
2. **Attention to artifacts** – a model of the quality and quantity of the attention that a given user pays to a particular exhibit or web page [8]. We are interested in such questions as: did the user look at a particular page? If so, did they glance at it or read some text on it, for example? Did the user pay attention to the exhibit or were they mostly preoccupied with their device? If they were preoccupied with the device, were they preoccupied with content on the device or with some issue (perhaps a difficulty) to do with the device itself?
3. **Paths through physical and virtual space** – here we are concerned with the sequence of points in physical space (exhibits) and virtual space (web pages) through which the user passes as they visit the museum. We are interested in events that signify a particular activity such as following a virtual link to get more information on a topic, making a decision to walk over to another exhibit, shifting attention back and forth between the physical and virtual at a single exhibit, patterns of use that signify preferences for physical versus virtual content, etc.
4. **Higher order effects** – models of higher order effects that are particular to the specific domain, in this case of a science museum, informal learning and related phenomena such as exploration and reflection.

Figure 3 shows a path taken by a user while they visit two exhibits. The user shifts their attention back and forth between the first exhibit and some web pages, then they decide to move to another exhibit, where they pick up a link but then quickly decide to move elsewhere. Construing what happened here requires detailed information on such factors as when and where some attention to an artifact took place, what type of interaction took place, for how long, at what level of scrutiny, under what circumstances of system responsiveness, lighting conditions, user skills, etc.

3.1 Methodology

We have developed a system for automatically logging basic events such as accesses to web pages, in particular to web pages obtained from a beacon or a barcode. Thus we have detailed information on virtual locations but only some information about physical location.

We need to capture higher-level information such as whether the user was having trouble with the device or whether the user appeared to pay attention to a particular web page or ignored it. For that purpose, we are personally observing users and shall be recording them on video. Synchronization of clocks between the web logs and the personal observations enables us to correlate the two. As well as performing measurements, we obtain qualitative and more subjective data through pre- and post-visit questionnaires and/or interviews. These are designed to help us find out what the users felt to be the quality of the information provided (including its presentation).

Currently we ask users simply to browse however they are inclined to do so. We are considering asking users to perform specific tasks, such as visiting a particular page from a particular exhibit and meeting a challenge such as answering a question about a collection of exhibits, in order to understand phenomena that occur too variably or not at all under simple browsing.

4 Discussion

We have outlined a project that aims to study the use of technologies for 'bridging the physical and virtual worlds' in a museum setting. Many other projects have developed prototype or commercial systems for museum augmentation or navigation with handheld and/or wireless technologies – an excellent overview is available in [2]. However, very little of the published research reports on results from extensive user studies [19] or on extended engagement with the system before and after the visit, for example the kind that we envision when the visitor's museum experience is captured and available for future reflection.

Our research will focus on the types of physical-and-virtual navigation that are possible with CoolTown technologies and that are not exclusive to the museum setting. Our belief is that studying the shifting of the user's attention between such factors as the exhibits, the content about the exhibits, the user's companion, and the technologies themselves will lead towards more universal design implications for these kinds of systems.

This project is in the early stages. We are resolving issues with the logistics of technology installation and the preparation of realistic content, and have only conducted preliminary dry-runs with users. During the Summer 2001 we plan to refine our research questions as outlined by our four-level model of user behavior and to conduct a user study focused on the basic affordances of the system.

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