Design and Development of Four Prototype Interactive Edutainment Exhibits for Museums

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Abstract. This paper describes the outcomes stemming from the work of a multidisciplinary R&D project of ICS-FORTH, aiming to explore and experiment with novel interactive museum exhibits, and to assess their utility, usability and potential impact. More specifically, four interactive systems are presented in this paper which have been integrated, tested and evaluated in a dedicated, appropriately designed, laboratory space. The paper also discusses key issues stemming from experience and observations in the course of qualitative evaluation sessions with a large number of participants.

Keywords: Interactive exhibits; edutainment; museum; interaction design.

1 Introduction

In the past few years, several museums worldwide started exploring new ways for integrating novel interactive exhibits in their spaces, moving beyond the typical "multimedia information kiosk" paradigm of the past (e.g., [3; 4; 9; 12; 20]). In the context of the "Ambient Intelligence and Smart Environments" Programme of the Institute of Computer Science of the Foundation for Research and Technology – Hellas (ICS-FORTH), a multidisciplinary project was set up aiming to explore and experiment with the creation of novel interactive edutainment exhibits for museums and assess their utility, usability and potential impact. This paper presents four representative systems that stemmed from this project - mainly targeted to archeological and historical museums. Since October 2010, updated, appropriately adapted, versions of all four systems are installed and available to the general public at the Archaeological Museum of Thessaloniki, Greece, as part of a permanent exhibition of interactive systems.

2 Related Work

Worldwide, there have been a number of museums that installed, temporarily or permanently, interactive exhibits in their premises. For example, the "Re-Tracing the

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Past" exhibition of the Hunt Museum was designed to show how novel interactive computer technologies could be introduced into a museum setting [3]. The "Fire and the Mountain" exhibition comprised four hybrid exhibits [4] aiming to promote awareness about the cultural heritage of the people living around the Como Lake. The Austrian Technical Museum in Vienna opened a digitally augmented exhibition on the history of modern media [9]. ARoS, an art museum in Denmark, employed four interactive exhibits targeted to an exhibition of the Japanese artist Mariko Mori [12]. The Ragghianti Foundation held an exhibition entitled "Puccini Set Designer" [20] that used new technologies to convey to the audience Puccini's work as set designer.

The creation of interactive exhibits also led to the development of a considerable corpus of knowledge related to their design. In this respect, Durbin [2] describes the design process and observation results of "interpretative devices" integrated within the displays of the British Galleries of the Victoria and Albert Museum. Lehn et al. [14] examine the ways in which visitors encounter and experience exhibits and how these experiences are shaped and affected by social interaction. Hope at al. [8] focus on issues of family interaction and cooperation in a technological-augmented museum, while Walter [21] and Heath et al. [7] provide observation study results from the use of electronic guides and interactive exhibits respectively, and identify several problems and trade-offs between interactive media use and social interaction.

The work presented in this paper builds upon and extends previous knowledge and efforts, aiming to create a set of re-usable and customizable interactive components that can support basic museum visitors' needs and requirements and accommodate a variety of content. To this end, the use of a common middleware layer by all systems facilitates the future integration of diverse add-on components, as well as the intercommunication among the exhibits.

3 The Interactive Exhibits

This section presents in detail the four prototype exhibits created after several cycles of iterative design, prototyping and evaluation. All exhibits were enriched with indicative, scientifically valid, content, mainly targeted to archeological and historical museums. When the preliminary spatial design of the exhibits had reached a fairly stable level, a dedicated space (14x6m^2) was appropriately adapted to house them. An in-house custom-made middleware layer based on CORBA was used in all the exhibits to allow the interactive applications and various software services (e.g., computer vision modules) to intercommunicate. In this context, the applications running on all systems were developed using Flash ActionScript, while the low-level services that drive the hardware sensors were implemented in .NET (C#) and C++.

3.1 Macrographia: Exploration of Large-Scale Artifacts in Real-Life Size

The system is installed in a room (6x6x2.5m^3) in which a computer vision subsystem with 8 cameras tracks the position of visitors (for more details see [23]). On one wall a dual-projector back-projection screen (4.88x1.83m^2) is installed. Behind the screen lies a control room that contains two 1024x768 short-throw projectors, stereo speakers and 3 workstations. In the main room there is also an information kiosk and a stand with mobile phones. Mobile phones run a custom application that can receive information about their holder's position and render information accordingly. Localization of persons is performed at 10Hz and has an accuracy of ~2cm. Macrographia (Fig. 1 - left) can present large scale images of artifacts, with which one or more visitors can concurrently interact by walking around, thus effectively applying interaction techniques used by interactive floors (e.g., like the iGameFloor [6]) in a different application domain, also extending previous related approaches like [12] and [20] through multi-user support and personalization. In the Macrographia demo installation, the projection screen presents a wall painting that is originally located on the façade of the tomb of King Philip II in Vergina, in northern Greece. Visitors enter the room from an entrance opposite to the display. The vision system assigns a unique id number to each person entering the room. As two help signs illustrate, visitors entering the room from the right-hand side are considered to be English-speaking, while those from the left-hand side, Greek-speaking. When at least one person is in the room, a piece of music starts to play. The room is conceptually split in 5 zones of interest, delimited by different themes presented on the wall painting. These zones cut the room in 5 vertical slices. The room is also split in 4 horizontal zones that run parallel to the wall painting, which are delimited by their distance from it. Thus, a 5x4 grid is created, comprising 20 interaction slots. Fig. 1 (right) presents an illustration of the grid, as rendered by a support application, responsible for orchestrating interaction. The image presents three users located at different slots. When a visitor is located over a slot, the respective wall painting part changes and, depending on the slot's distance from the wall, visitors can see a sketch, a restored version or a detail of the wall part, accompanied by related information.

Fig. 1. (left) Overview of the Macrographia system; (right) Macrographia zone map

Fig. 2. Macrographia: Wall painting status corresponding to the location of the users in Fig. 1

All information is presented in the user's preferred language. Since users are associated with a unique id, the system keeps track of the information they have accessed, as well as of the time they have spent on each slot. Apart from location-sensing, Macrographia also supports two more types of interaction: (a) a kiosk and (b) mobile phones. The kiosk offers an overview of the wall painting, an introductory text and two buttons for changing the user's language. All information is automatically presented in the visitor's preferred language. Furthermore, the wall piece in front of which the visitor has spent most of the time is highlighted. Mobile phones are used as multimedia guides, automatically presenting images and text (that can also be read aloud) related to the visitor's current position.

3.2 Panoptes: Browsing Collections of Artifacts

Panoptes (Fig. 3 - left) builds upon the concepts of playful [11] and aesthetic [18] interaction combining functionality with playfulness and serendipity, thus offering an alternative to information kiosks used at museums for browsing item collections. The system comprises a "wall" ($1.55x1.9m^2$) on wheels, two framed touch screens, a webcam, a light sensor and a custom windmill sensor. The larger screen (19'') presents a high resolution photo of the currently selected artifact. The smaller one (12''), presents information about the artifact and also includes some soft buttons. Different types of content were used to test Panoptes, such as famous paintings and ancient Greek jewelry. The large screen supports two types of interaction:

a. ***Hotspots*:** Each image can include any number of hotspots. If the user touches one of them, the corresponding area is highlighted and a word balloon pops-up with related information (Fig. 3 - right). If the user touches any part of the image that does not include a hotspot, then all the available hotspots are highlighted (Fig. 3 - middle) in order to provide feedback about their position.
b. ***Magnification*:** If the user drags her finger on the image (for a distance longer that 1cm), she starts drawing a yellow line with which she can circle an area of interest. When the user moves her finger off the screen surface, the selected area is magnified. The user can subsequently iteratively zoom into the selected area.

Fig. 3. (left) The Panoptes system; (middle & right) available hotspots & hotspot selection and information presentation

A visitor can browse all the available artifacts by blowing at the windmill (or just rotating it with the hand). The windmill's speed affects the browsing speed but also triggers alternative music pieces originating from old music boxes.

The smaller screen comprises a framed photo of the current artifact, visually linking its contents with those of the larger screen, brief information that depends on the artifact type, a descriptive title and a short text. The screen also offers buttons for browsing/navigating through the collection of artifacts, accessing a gallery of all artifacts through which the user can select one for viewing, and language selection. Above the screens there is a camera and on top of the wall a light sensor. The function of this sensor is to detect flash photography. In such a case, the web camera is used to take a photo of the visitor photographing the exhibit. This was initially meant to be just a fun "hidden" feature, but, eventually, as *in situ* observations have revealed, it became a very engaging interactive characteristic (for further details, see Section 4).

3.3 Polyapton: Familiarization with an Artifact and Information Discovery

Polyapton is a large size (1.6x1m^2) custom-made multi-touch screen. The system builds upon the combination of IR illumination and semi-transparent back projection screen (e.g., [13; 15]) and consists of (see Fig. 4): a grey level camera equipped with an IR filter, 8 IR illuminators, a projector that is projecting through a mirror on a rear-projection acrylic rigid screen backed up by a thick layer of glass, and a workstation. All the electronic equipment is hidden inside a control room. In addition to multi-touch, the system supports interaction using three props: (a) a "magic wand", i.e., a

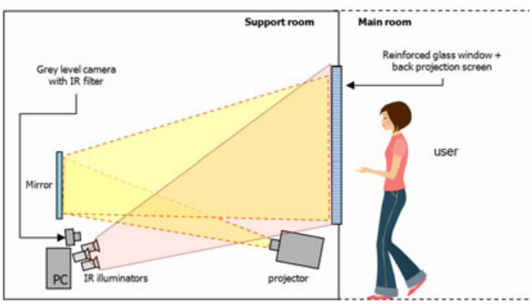

Fig. 4. Polyapton schematic installation layout

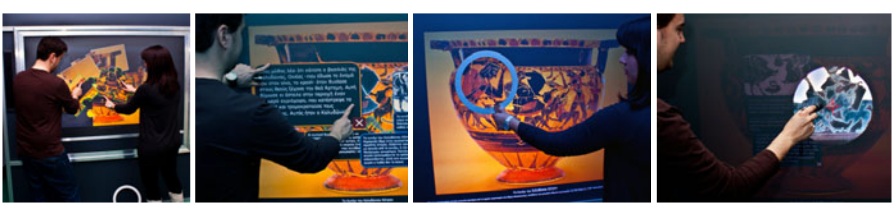

Fig. 5. (left-to-right) (a) collaborative puzzle construction; (b) information discovery; (c) prop-based information discovery, using a paper magnifying lens; (d) using an IR torch

stick with an IR led; (b) a magnifying glass made of white cardboard (working like the transparent lens in [10]); and (c) an IR flashlight (the use if which was inspired by [17]). The basic principle of operation and details of the vision system of Polyapton are described in [16]. The system initially presents a photo of an artifact (e.g., ancient vase) and a short descriptive title. When a user touches the screen, the image breaks into several puzzle pieces that are randomly scattered around. This activity was selected because it leads visitors (in a subtle and fun way) to explore and focus on details of the artifact at hand. A faded grey-scale image of the completed puzzle is shown at the background as a help guide. Multiple users can cooperate to place the pieces at their correct position (Fig. 5a). Pieces can be moved using any number of fingers, and, in order to be rotated, at least two fingers must be used. If a puzzle piece is touched by the magic wand, then it is transferred to its correct position. When the puzzle is completed, a short description appears underneath the image and several hotspots are momentarily highlighted over it. If users touch on a hotspot, an information box appears, containing text that is occasionally accompanied by an image. Users can move the boxes around and also resize them (Fig. 5b). If a user points the IR flashlight towards the screen, then the image turns black, and a circular area is highlighted, corresponding to the flashlights projected “light” (Fig. 5d). This area simulates an “X-ray” view of the artifact that includes hidden hotspots. If the flashlight stays over a hotspot for more than one second, then an information box with related information pops-up. Finally, if a user places the paper magnifying glass on the display, then the respective part of the image is magnified (Fig. 5c).

3.4 PaperView: Exploration of Terrain-Based Information

PaperView [5] (Fig. 6) is a tabletop augmented reality system that builds upon Wellner’s [22] DigitalDesk concept in combination with Reitmayr et al. [19] augmentation of paper-based cartographic maps using real world objects, but taken further, since multi-user interaction, finger-based input and concurrent tracking of diverse border colors are supported. The system’s main component is a table (1.8x1m^2), the surface of which is covered by a printed map. Underneath the table there are two speakers and high above it, a video projector, an IR camera and an RGB camera. Next to the table

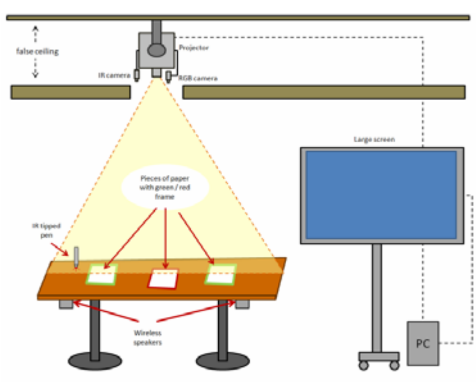

Fig. 6. PaperView schematic installation layout

lies a 56'' HD TV screen, bearing a shelf with a stack of rectangular pieces of white cardboard. One side of each piece is framed with a thick green line, while the other with a red one. Additionally, a pen with IR led tip (i.e, like a mini-torch) is available on the table, the position of which is tracked by the IR camera. Details about the vision system of paperView are described in [5].

Initially, the projector overlays on the map the location and names of sites with archeological interest (in English and Greek). If a visitor places a cardboard piece on the table surface, the area of the map located underneath the paper, as seen in Google Maps ("map mode") is projected on it. Furthermore, a circled crosshair is projected on the paper's centre. If the visitor moves the paper so that a site of interest lies within the boundaries of the crosshair, a multimedia slideshow starts ("info mode") comprising a series of pages with text, images, and video. The frame color is used as a means for implicit language selection (green = Greek, red = English). When the cardboard piece is lying on the table, a toolbar is projected at its lower bottom area, containing the current page number, and buttons for moving to the next/previous page. The user can interact with these "soft" buttons using her bare fingers (Fig. 7b). If the paper is taken off the table's surface, the buttons disappear and the user can move to the next/previous page, by tilting the paper right or left, respectively. In this case, the projection is appropriately distorted (Fig. 7c), so that the visual content registers correctly on the paper surface. In order to avoid accidental browsing actions, page change does not happen instantly. Instead, an arrow-shaped progress bar is presented on the paper (Fig. 7d) and takes about 1 sec to fill. In order to visually link information presented on a cardboard piece to the site it refers to (since it may have been moved away from it), a connecting string is used. The TV screen presents a Google Maps view of the geographical area covered by the printed map. Visitors can use the pen on the table to navigate in Google Maps. Also, if the user selects a point of interest, related multimedia information is presented. If a user keeps the pen at the same position for more than 1 second, a virtual remote control appears, through which she can zoom in/out in Google Maps and select alternative map views.

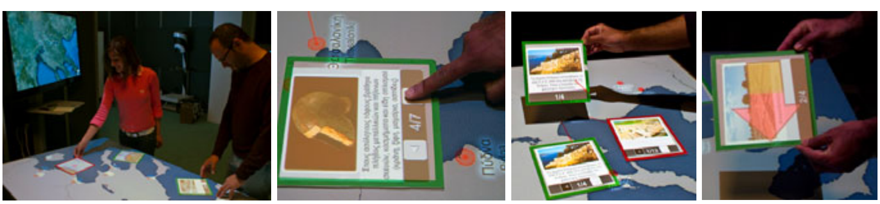

Fig. 7. PaperView usage: (left-to-right) multi-user interaction with the map; pressing the soft buttons; lifting the paper above the table surface; tilting the paper to browse content

4 Evaluation and Discussion

Ethnographic field methods [1] were adopted for the formative evaluation of the exhibits, using a combination of the "observer participant" and "participant observer" approach. To this purpose, the exhibits were installed in a dedicated space, resembling an exhibition area of a museum. Additionally, one of the exhibits (Panoptes) was installed for one month in a temporary art exhibition. During this preliminary evaluation phase, more than 100 persons of various ages and educational and technological backgrounds have participated. Overall, the opinion of all participants about the exhibits ranged from positive to enthusiastic. Usually, when visitors were first introduced to the exhibits there was a short “wow” phase, during which they seemed fascinated by the technology and tried to explore its capabilities, but, interestingly, after that, most of them spent considerable time exploring the exhibits’ content. The remainder of this section summarizes some key observations and conclusions:

Playfulness vs. Controllability**:** Originally Panoptes supported browsing only through the windmill. At first, this worked great, but as visitors started to explore the content in depth, they required more deterministic interaction control – especially when they wanted to make sure that they have seen everything that was available. As a result, next/previous and gallery buttons were added.

Tangible vs. electronic interaction**:** There is no doubt that interaction through tangible objects made big and lasting impression to all participants, also gaining their preference. As numerous technological gadgets have entered everyday life, adding “magical” properties to everyday objects combines familiarity with an element of surprise. On top of that, tangibles provided simple, straightforward interactions.

Fun vs. Robustness**:** Since the exhibits were evaluated at various maturity levels, sometimes participants faced system misbehaviors, or even crashes. As it turned out, if visitors had fun while using a system, they would not abandon it even if it presented unstable or erratic behavior.

Implicit vs. Explicit Controls**:** An issue that still remains open regarding the Macrographia application, is whether the interaction slots should be explicitly marked on the floor or not. On the one hand, explicit indications would provide visible controls and more “crisp” interaction, but on the other hand, the changes that happen on the projection screen accompanied by audio cues, provide indirect feedback supporting more exploratory, casual, interaction.

Intended vs. unintended actions in location-based interaction**:** When a visitor was crossing Macrographia an avalanche of wall changes were triggered. As a solution, a minimum dwell time was adopted, in order for a user to gain control over a slot. Another “grey area” was the room’s entrance. Since very often people were just peeking in on before engaging, the only functionality assigned to the zone close to the door was language selection and start of music.

Interaction fuzziness**:** Visitors standing at the boundaries of slots in Macrographia would sometimes be in a state of accidentally switching between them. To remedy this problem, the slot’s area that the user is on is enlarged by 10%.

Visitor self-centeredness**:** The photo-taking functionality of Panoptes was initially conceived as a hidden function. But when Panoptes was installed at the art exhibition, one visitors accidently discovered it and then, somehow, this information became a common secret that was propagated from the older to the newer visitors and eventually, everyone would stand at least once in front of the exhibit just to have his photo taken and presented in it. Some people would call their companions and family to get a group shot, or some others would surprise their unaware friends by taking sneak photos of them in funny poses.

Level and type of instruction**:** Children were observed to experiment with the exhibits even if no instructions were available or nobody explained their use to them. Adults were more reluctant to experiment. A strong preference noted was staying in the back and looking at others using the exhibit. To the other end, there were people that seemed to enjoy explaining the exhibits to their friends, or even to strangers. In some cases, minimal prompts acted as an incentive for initiating interaction. Most participants stated they would not like to have to go through written or pictorial instructions.

Language selection**:** It was found out that different exhibits require different approaches. For example, the kiosk was initially used as a means for language selection in Macrographia. This created problems of visitor flow and erratic system behavior. The current scheme of implicit selection was a great improvement in terms of both usability and robustness. Similarly, at first, paperView users had to select their language from a dialogue appearing on the cardboard, every time it appeared over the table. By selecting language through frame color, this step was eliminated.

5 Conclusions and Future Work

As a six-month period of iterative formative evaluations with a highly diverse, group of participants has shown, all exhibits achieved the goal of providing engaging and entertaining educational experiences. The suitability towards their goals is indicated by the fact that the Archaeological Museum of Thessaloniki, one of the most prominent museums in Greece, installed an updated version of the presented systems (appropriately adapted to the museum's collections) along with some additional ones as part of a its permanent exhibition "Macedonia: From fragments to pixels"[1].

Since all exhibits use a common middleware layer, although they currently operate as stand-alone systems, future work includes their semantic connection in order to create a seamless interaction flow, offering to visitors a unified experience. By employing alternative identification technologies, all systems will be able to recognize their users, fetch interaction history with other exhibits and adapt their content, presentation and behavior accordingly. At a lower level, additional capabilities will be added to all exhibits, such as spatial sound, posture and gesture recognition to Macrographia, multi-screen interaction and gesture recognition to Polyapton, non-speech audio input to paperView, etc. Finally, future work includes investigating the application of the project's results in different types of museums.

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