Cognitive Technologies

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PEACH – Intelligent Interfaces for Museum Visits

With 101 Figures, 32 in Color, and 16 Tables

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Preface

This book reports the main results of the Personal Experience with Active Cultural Heritage (PEACH) project, whose goal was to produce intelligent tools, or, more ambitiously, an environment for making a visit to a museum a rewarding experience. PEACH was a large four year project funded by the Autonomous Province of Trento, exploring novel technologies for physical museum visits developed at ITC-irst (Institute for Scientific and Technological Research), Trento and DFKI (the German Institute for Research in Artificial Intelligence), Saarbrücken. The aim of the project was to significantly increase the quality of cultural heritage appreciation, in such a way as to transform passive objects into an active experience.

A visit to a cultural site with a friend who knows the subject well and who knows the visitor has been a precious experience for centuries. Through time, with the development of museums and the emergence of the cultural experience as a mass phenomenon, tools for museum communication have been introduced: labels illustrating exhibits, guidebooks, and guided tours. Following this, different forms of technology were introduced such as audio material on cassettes and later CDs (having the advantage of providing random access) as well as visual material through various forms of kiosks, screens, or presentation rooms. In some museums, coarse-grained localization systems have been introduced as well that let the system automatically know what room the visitor is in, so that the presentation recorded for that room can be automatically selected. In very recent times, mobile computing and wireless communication have also begun to be used in some museums.

A cultural visit is a blend of cognition, emotion, and social communication; perhaps it is the most central case of educational entertainment. The end goal is for people to enjoy the process of acquiring knowledge, to understand more about the past, to appreciate art, and, through this, to develop an interest for the site and, possibly, for a subject (archeology, history, art).

From a scientific point of view, cultural heritage appreciation is an ideal area for exploring new concepts in intelligent user interface research and dealing with a privileged educational entertainment issue. Various large themes of research are relevant. The introduction of new devices entails an interesting application and experimentation arena. This theme includes development of sensors, communication devices, novel wearable computers of various kinds, and also what we can describe as the consequences of their adoption at the system level.

A second large theme includes the higher level techniques for solving specific applied challenges. Some examples include developing artificial vision techniques appropriate for supporting a visit, or developing specific language processing techniques useful for retrieving the important information or dealing with flexible language presentations starting from retrieved information of all sorts, even designing novel infrastructural technologies with features that help realize a complex system and adapt it to the specific context smoothly.

A third even larger theme puts the visitor at centre stage. It includes issues such as novel user interfaces, intelligent multimodal presentations, and the educational and the cognitive technologies that can be developed for best serving the visitor in his or her experience. For instance, recent original work brings the affective dimension into technology for the museum experience. There are more issues to be addressed, including the dimension of the overall impact of the technology that requires novel research and most likely the introduction of novel methodologies.

Another very important theme (not directly addressed in this volume) is the even greater divide that many of the advanced technologies impose on the elderly and on individuals with disabilities. Rarely do novel devices and interfaces take into account the fact that a portion of the population is not at ease with the new offer and might simply be excluded. Flexibility and adaptability along this dimension must become an important topic of research, so that end products can incorporate disabled-friendly features without great effort. In this respect, the importance of research on multimodal interfaces cannot be overemphasized. For instance, the flexible, intelligent allocation of the message on a combination of available modalities can be a fundamental resource. In the applied scenario, a system must take into account the user's ability to function easily using the possible modalities included in the interface.

This book is an edited collection of papers describing the results achieved in PEACH. The work in the project was interdisciplinary: the technologies belong mainly to the area of intelligent user interfaces, but included other areas of artificial intelligence, microsystems and computer–human interaction. The studies conducted in PEACH resulted in the construction and evaluation of various prototypes. Together they offer an innovative applied prospect for the field of cultural heritage appreciation.

The volume is structured in six parts; each of the first five parts includes several chapters concerned with different areas of the project. A final chapter discusses directions for the future.

The first part deals with the common theme of the development of an intelligent, user-adaptive mobile guide.

The chapter 'Adaptive Multimedia Guide' presents the evolution of a multimedia adaptive, mobile guide. The museum visit is a complex experience that encompasses cognitive and emotional aspects. Visitors have different ways of elaborating background and new knowledge, and they have different interests and preferences. Designing interactive technologies to support such an experience requires effort in many aspects: the graphical interface and its usability, the adaptation mechanism and its effectiveness, and the overall satisfaction of the visitor. Moreover, technology designers need to consider the intrusiveness of the devices they propose for supporting visits. The starting idea of the work presented is that an adaptive guide that offers highly personalized information can help each visitor to accommodate and interpret the visit according to his or her own pace and interests. Hence classical audio presentations were enhanced with video documentaries—small, adaptively composed video clips—which help visitors to identify exhibit details mentioned in the audio counterpart and to show the relationship between new and previously presented information without interfering with the appreciation of the exhibit itself. In developing the guide, a user-centred design approach was adopted that includes a requirements elicitation phase and a number of iterative design steps. The results achieved at each stage are described. In particular, the evolution of the interface is in focus: its acceptability and usability after each redesign, and details on the changes required in the system backend. The main result of this process is the final prototype with an interface based on affective interaction. The prototype device, a PDA with specialized software, lets visitors express their attitudes about an exhibit using a graphical widget, the *like-o-meter*, which allows users to express preferences with four degrees of freedom. In addition, it enables them to explicitly signal their interests in order to guide the adaptation mechanism of the system. Another issue considered in this chapter is the preparation of adaptive content. Writing content for adaptive guides is a difficult task for authors, even for professional multimedia authors. The experience of involving two multimedia authors in the content preparation for the adaptive mobile guide is described, with details on how the authors were trained, how the system's adaptation mechanisms were explained to them, and, finally, the methodology (and the functionalities to be implemented in an authoring tool) for, in the future, reducing involvement of the engineers (who usually are not part of a ‘standard’ museum staff) during the content authoring phase.

Video documentaries are often integrated into information technology solutions that support cultural heritage exploration. However, high production costs of human authoring and lack of personalization hamper wide adoption of this technique. Automatic approaches are called for. Yet, automatically constructing a complete documentary or educational film from scattered pieces of images and knowledge is a significant challenge. Even when this information is provided in an annotated format, the problems of ordering, structuring, and animating sequences of images and of producing natural language descriptions that correspond to those images are each difficult tasks. The chapter ‘Cinematographic Techniques for Automatic Documentary-Like Presentations’ describes the PEACH approach to dealing with these problems. Rhetorical structures combined with narrative and film theory produce movie-like visual animations from still images. Natural language generation (NLG) techniques supply text descriptions for the animations. Rhetorical structures from NLG are used as a common denominator to assure coherence when merging work done by separate components for video creation and script generation.

The chapter ‘Detecting Focus of Attention’ explores different means by which the focus of attention of the visitor, i.e., the local context, can be determined and exploited in the context of intelligent systems for cultural heritage appreciation. Two different modalities of interaction of a visitor with a smart museum are considered. In the first one, the user reveals his or her interest by pointing a PDA with a camera at an exhibit. The PDA then feeds back properly contextualized information to enhance comprehension of the exhibit. Image processing techniques are used to recognize the paintings (or details thereof) viewed by the PDA camera. Once a painting is recognized, the PDA accesses relevant database information over a wireless connection. The second scenario does not require a helping device to point at the item of interest: rather, head orientation and arm gestures are directly used to determine focus of attention. The first, mediated method works well in supporting a single user in the natural exploration of museum exhibits. The system knows the layout of exhibits, permitting it to identify focus of attention by finding the intersection of the line of sight with the geometry of the environment. The second system, relying on the interpretation of deictic gestures, works well as a support to a guide who conducts and informs sightseers, but it is an unnatural way for a single visitor to interact with a museum. The smart museum can monitor the guide during his or her informative efforts, presenting additional multimedia material whenever he or she points at active spots in the exhibits.

How intelligent technologies can intervene at the end of the visit is the topic of the chapter ‘Report Generation for Post-Visit Summaries in Museum Environments’. As guardians of cultural heritage, museums are interested in a continual presence within their communities for both ongoing learning and improved public awareness of their collections. Thus an additional area where the technology demonstrated in PEACH can have an important impact is the extension of the museum’s influence outside the confines of the museum itself. Personalization is one key to heightening this impact, where a permanent keepsake is given to a visitor upon his or her exit from the museum which describes his or her unique experience and is immediately recognizable as such. Language technology may be used in order to accomplish this goal of continuing to educate a visitor after the museum visit is completed, and to provide the ‘hook’ of specific personalization leading to further visitor interest. In order to construct this personalized keepsake, the sequence of interactions with the intelligent tour guide during the visit is used to predict which exhibits the visitor was most interested in. The system then produces a page-long report summarizing the visitor’s tour, the artworks he or she found most interesting as well as those he or she missed out on. The system also provides additional information linked to what he or she has already discovered and that could be used to discover new information via the Internet. The prototype described in this chapter produces written report summaries given an interest model described previously for the Torre Aquila museum, printed on demand, including colour reproductions of the referenced artworks, and in either English or Italian.

The second part deals with infrastructure and user modelling. As discussed before, context awareness is a key feature of applications for active environments, such as PEACH’s automatic visitor guides. Most existing works consider context as information neutral with respect to the agents acting in the environments, thus it can be represented in some form of shared knowledge base. By contrast, in the chapter ‘Delivering Services in Active Museums via Group Communication,’ context is viewed as a specific perspective of each agent on its environment; what is needed is a way for agents to be systematically aware of what happens in their surroundings, i.e., they must be able to ‘overhear’ events and interactions. Group collaboration is possible when collaborative agents immersed in the same environment are reciprocally aware of their capabilities and their likely states as a consequence of a history of events. Such context awareness can also be obtained via overhearing. From a communication perspective, overhearing requires some form of broadcast facility, in PEACH a mechanism called ‘channelled multicast’ has been tested. In this chapter, the motivations for this approach are presented, the architecture for active environments based on implicit organizations is introduced, and implicit organizations can be applied in practice. A short overview of the work concerning its formalization in logic and as a design pattern is also introduced.

The chapter ‘User Modelling and Adaptation for a Museum Visitors’ guide’ touches upon the underlying infrastructure for producing personalised information for the individual. The museum environment is rich with information that can be presented to visitors; there is more information to be delivered than time available for the visit. Supporting personalization is a particularly challenging task in the museum environment where ‘non-intrusiveness’ is fundamental. User modelling has to take advantage of the observation of events and behaviour, and needs integration of various techniques. Within the PEACH project, several adaptation and personalization techniques were tested, integrating a variety of technologies as sources for information about visitors’ positioning data and visitors’ interests. PEACH also faced the challenge of bootstrapping a user model (when no initial data is available) and the requirement for ‘lean’ user modelling—using whatever information is already available without additional specific information. Moreover, user modelling was exploited for two services in particular: dynamic presentation and visit summary report generation, each with different specific requirements.

The third part is dedicated to novel uses of stationary devices, in one case integrated in the mobile experience, in another as a specific application for children.

In the chapter ‘Integration Between Mobile and Stationary Devices’ the PEACH activities related to the integration of information presentation of the mobile tour guide, based on a PDA, and large stationary screens, the so-called virtual windows, are presented. Relevant interaction concepts as well as the software architecture that integrates both device types are discussed and experiences from two prototypical installations in the museum ‘Castello del Buonconsiglio’, and the ‘Völklingen Old Iron Works’ are presented. The accent is on the use of virtual characters, a remote-control metaphor, and a voting mechanism. Different phenotypes of the characters were designed to fit the small screen size of the PDA and, at the same time, to be able to perform communicative acts based on gestures. The remote control metaphor was used to allow visitors to individually control the presentations on the virtual windows, while the voting mechanism helps to solve conflicts in situations where more than one visitor is standing in front of the virtual window. The client–server based architecture can handle and manage several mobile devices and several virtual windows. The content is synchronized and retrieved from a common database and its presentation is driven by a script language. The architecture can also be used to collect statistical data on movement patterns of visitors. This data can then be analysed to understand more about the users' interests and to adapt the presentation of content both on the mobile and stationary device.

The next chapter reports about an innovative technology for children. For children in a museum environment, an active role is essential. It is also appropriate to stimulate shared 'cultural' activity and in particular a reflective process after the museum visit. The chapter 'Children and a Museum: an Environment for Collaborative Story Telling', describes a system called Story Table, which is aimed at supporting pairs of children in the activity of storytelling, a fundamental aspect of the reflective process. The system is based on a multiuser touchable device (the MERL DiamondTouch) and was designed with the purpose of enforcing collaboration between children. The chapter discusses how the main design choices were influenced by the paradigm of cooperative learning, and presents two observational studies to assess the effects of different design choices on storytelling activity. Finally, a study involving 70 children from a local primary school is presented. The experiment demonstrates that the use of Story Table compared to the control situation improves the quality of the interaction and, to some extent, the quality of the stories produced.

The fourth part is concerned with visual technologies for reconstruction and for simulation and control in the museum environment.

3D virtual reconstruction and modelling offer an important prospect for cultural heritage. They aim at creating highly accurate and realistic digital copies of artworks and monuments of particular cultural interest. Advances in microelectronics, microsystems, photonics and computer vision in the last decade have led to the development of faster and more reliable methods for 3D digitization of objects of nearly any shape at ever decreasing costs. The topic of photorealistic virtual 3D reconstruction of objects and architectures was approached within PEACH in two independent, different ways. The first approach, directed towards the digitization of large architectonic structures and buildings, deals with image-based modelling based on close-range photogrammetry. The second approach, directed towards the digitization of free-form objects, deals with the development of a new concept of integrated sensors for triangulation-based 3D laser scanners with improved performance in terms of dynamic range, readout speed, and multiwavelength detection. The chapter 'Photorealistic 3D Modelling Applied to Cultural Heritage' reports on the 3D modelling techniques used within PEACH, the results achieved during the project, and the challenges for the future.

Automatic monitoring of people wandering within a large, multiroom environment such as a museum provides information which supports increased security for and better planning of exhibits. The chapter 'Tracking Visitors in a Museum' describes a modular processing architecture for distributed ambient intelligence which provides a detailed reporting of people's trajectories in complex indoor environments. The design of the architecture was driven by three main principles: reliable algorithm testing, system scalability, and robust performance. The first goal was achieved through the development of Zeus, a real-time 3D rendering engine that provides simulated sensory inputs associated with automatically generated ground truth. Scalability was achieved by developing a novel modular architecture for multiplatform video grabbing, MPEG4 compression, and stream delivery and processing using a local area network as a distributed processing environment. Robust performance was attained with the introduction of a theoretically well-founded Bayesian estimation framework that allows for the effective management of uncertainty due to occlusion. The performance of the algorithms is reported for a virtual museum where groups of simulated visitors with different cultural interests move freely.

The next part deals with evaluation with users and usability issues which are, of course, of essential importance in the museum.

The chapter 'Evaluation of Cinematic Techniques in a Mobile Multimedia Museum Guide Interface' discusses the use of cinematic techniques in building mobile multimedia museum guides. The hypothesis is that a user interface that employs cinematic techniques reduces the inherent invasiveness that the PDA brings to the museum experience. The results of an initial evaluation that was conducted with 46 visitors are presented, and the evaluation supports the claim that cinematic techniques help influence the attentional behaviour of the visitor by reducing the number of eye shifts between the guide and the environment.

In PEACH, in addition to traditional evaluation performed within iterative user-centred design, attention was given to aspects not yet addressed by the community of adaptive interfaces, nor in the domain of museum guides. Two of them are discussed in 'Innovative Approaches for Evaluating Adaptive Mobile Museum Guides'. The first approach is aimed at assessing the visitors' attitudes towards several basic dimensions of adaptivity relevant for museum guides and the possible relationships between personality traits and user preferences towards those adaptivity dimensions. For this evaluation two simulated systems were used that realized an adaptive and a nonadaptive version, respectively, on each of the dimensions investigated. The study showed that the personality traits relating to the notion of control (conscientiousness, neuroticism/emotional stability, locus of control) have a selective effect on the acceptance of the adaptivity dimensions. The second approach aimed at assessing several aspects of the experience real visitors had while using an adaptive user guide during the museum visit. The data showed that a positive attitude towards technology determines greater sense of control, deeper involvement, more ease in using the guide as well as a better attitude towards its future use. Quite surprisingly, older visitors were much more favourable towards a future use of the guide than young visitors, although young visitors had generally a more positive attitude towards technology and they used the guide in a correct fashion more often.

The book ends with a chapter devoted to the future, in particular to a theme that we have just begun to address: technologies to support small groups of visitors.

To a large extent, intelligent interfaces in the museum are based on the concept of ubiquitous context-aware presentations oriented to the specific individual. Yet in most cases a museum visit is an activity performed in groups (small, like friends or families, or larger, like a class). In the chapter 'Intelligent Interfaces for Groups in the Museum' this perspective and various connected themes are introduced. Some of the main challenges are how novel technology can give a new meaning to shared presentations, how to allocate the message to members of a group, and how to foster communication within the group during and after the visit, how to favour an active intellectual attitude as a distinguished characteristic of the group experience. Related to this is the problem of how to model the group, how to take advantage of previous experiences, how to maintain the common interest in the future. Finally, a specific challenge is to go all the way to have contents emerge from contributions by a community of visitors, and to make them intelligently adaptable and expandable. The overall idea is that research on these themes will help the future experience in the museum be a radically more engaging and socially oriented experience than the one we are used to now.

Most of the experimentation in PEACH, including long evaluation sessions, was conducted at the museum of the Castello del Buonconsiglio in Trento. We would like to thank the Director Franco Marzatico for his constant support and enthusiasm. At the same time we would like to thank Meinrad Grewenig, Director of Völklinger Hütte in Saarbrücken, where various experiments were also conducted.

We are pleased to acknowledge the authorities of the Autonomous Province of Trento, who made this project possible by providing generous research funding as well as an enlightened vision of the future. We thank all the participants in PEACH. Not all were involved in this book even if they

were important for the development of components and prototypes not described here. Finally we would like to thank Brian Martin for his role in revising and formatting the material for this book.

New research is continuing from the results described here: may PEACH be a tasty fruit holding the seed of larger developments in intelligent technologies for cultural heritage appreciation!

Trento, Italy, February 7, 2007 Oliviero Stock and Massimo Zancanaro

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Part I
Intelligent Mobile Guides

1 Adaptive Multimedia Guide

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1.1 Introduction and Motivation

An important goal of museum practitioners today is to find new services that keep the museum a stimulating and up-to-date space for all visitors regardless of age (Verdaasdonk et al. 1996; Laws 1998). From this viewpoint, the information provided to museum visitors is a key component in improving their involvement and thus their attendance (Ravelli 1996). Therefore, technologies are considered a valuable resource for catching visitor attention and stimulating their involvement (Lin et al. 2005). Engineering and HCI researchers have seconded this need with several proposals consistent with this kind of environment, developing museum guides, information kiosks, web services, and progressively more intense multimedia (González-Castaño et al. 2005; Scarlatos et al. 1999). These solutions arose through considerable efforts in studying the museum environment, its communication and interaction potentialities, and interconnections with technology (Ambach et al. 1995). These studies focused on what museum audiences would like to see and learn, which visitor behaviors could be supported by technology, how to offer these technologies to visitors, and visitor attitudes towards these technologies (Silberberg 1995; Crowley et al. 2001). They demonstrated non-homogenous behaviors and interests, which provided an opening for adaptive strategies. Adaptive technologies enable visitors to get personalized information, that is, information related to their particular interest, context and path, without time pressure or the involvement of human guides. They considerably enrich what museums can offer visitors.

In this chapter, we present an adaptive mobile guide, which runs on a PDA and accompanies visitors in Torre Aquila. Communication between the visitor and the system is based on an affective interaction paradigm that allows the visitor to naturally express his or her interest in presentations regarding an artwork. The feedback is exploited by the system to adaptively select the information, according to an inferred user model built up during the visit. We investigated an interaction paradigm that allows the user to express affective attitude towards the presentations proposed by the system. We wanted to verify whether such interaction improved the efficacy of the interface, especially when technology should not hinder the "real" experience, as with museums.

The preparation of adaptive content is a difficult task for multimedia authors, even professionals. For example, writing texts for adaptive systems requires authors to exploit nonlinear writing techniques. In our case, it is even more complicated because the multimedia guide also requires experience in the mixing of text and pictures, along the lines of cinema. Moreover, authors should foster visitor engagement with artworks when organizing the exhibition, identifying communicative strategies, in particular. It is not surprising that many such professionals have a background in humanities (art, literature, and so on) and that they usually do not have knowledge of adaptive systems, and the steps necessary for preparing content for the purpose of personalized composition. In order to manage the adaptive system—and in particular to write and classify contents—the author needs to first understand the vocabulary, the concepts and definitions used by engineers to structure the adaptive system. In the last part of the Personal Experience with Active Cultural Heritage (PEACH) project, we studied this issue seriously, considering how to help authors accomplish the task of authoring adaptive multimedia content. We started from our experience in preparing content for the PEACH mobile guide, and defined a methodology to support authors in preparing the content for adaptive mobile guides. Our first goal was to identify a clear methodology to support authors in preparing "adaptivity-ready" content for a mobile guide. On this basis, we also proposed relevant functionalities of an authoring tool to help authors in writing and managing adaptive content. One of the first papers about adaptive hypermedia authoring is by Hongjing et al. (1998), which introduces a reference model for adaptive applications and which also encompasses the authoring phase. Petrelli et al. (2000) present a graphical interface for preparing content for the framework of the HIPS project. Hyper-Interaction within Physical Space (HIPS, Benelli et al. 1999) was a European funded project aimed at creating personalized presentations of museum exhibits. Recently, a series of workshops about authoring in adaptive applications was organized in conjunction with adaptive hypermedia and education-related conferences.[1]

[1] See http://www.win.tue.nl/~acristea/A3H/.

This chapter is structured as follows: first, we introduce the state of the art in the field of the mobile guides, illustrating the main achievements of the last 15 years. We then describe the evolution of the system—graphical interface and backend—across a set of three prototype-evaluation cycles. For each step, we illustrate the insights that drove the design of the next prototype. Finally, we provide a methodology to help museum curators organize the content of adaptive systems.

1.2 State of the Art

About 15 years ago, Weiser (1991) proposed a set of ideas about the future of computers in the next century. "Personalization" was one of the key words mentioned in that paper and later was identified as a key feature of ubiquitous computing systems (Abowd et al. 2000). In a series of attempts to port "office applications" to mobile devices, researchers realized that new features could be explored, including information sharing (Aoki et al. 2002), location and context awareness (Want et al. 1995; Cheverst et al. 1999), and adaptivity (Rocchi et al. 2004).

From the second half of the 1990s on, there have been many efforts to explore the potential of mobile systems. CyberGuide was a large project which aimed at exploring the use of a mobile, hand-held, context-aware tour guide (Long et al. 1996; Abowd et al. 1997). The authors illustrate both indoor and outdoor prototypes, explaining the issues of detecting user position and orientation, and discussing the choice of hardware, the appropriateness of communication media (audio or video), and the methodology of map representation.

The HIPS project focused on hyper-interaction (Benelli et al. 1999), which evolved from the earlier HyperAudio experience (Not et al. 1998; Petrelli and Not 2005). A novel aspect, with respect to previous projects, was the overlapping of contextual and personalized information on top of the physical space. The user experience is augmented because spatial and informational navigation occur at the same time. The system, set up in Museo Civico (Siena, Italy), used a hand-held device to support visitors in moving around, and in seeking information and guidance. Personalization was based on user position, and on interaction with the PDA and the surrounding physical space.

GUIDE is another successful mobile system (Cheverst et al. 2000). It supports tourists visiting the city of Lancaster (UK). Combining mobile technologies and wireless infrastructures, it tailors information to the user's personal and contextual situation. Its design, carried out in collaboration with experts in the field of tourism, is particularly valuable and the insights gained during evaluations brought interesting changes to the prototypes.

Survey papers have helped assess the development of research from different perspectives. For instance, Kray and Baus (2003) present a survey of mobile guides, both prototypes or commercial, whereas Raptis et al. (2005) attempt to classify current practices in the design of mobile guides for museums.

Some systems featuring mobile guides are DiscoveryPoint, the Genoa Aquarium Guide, and SottoVoce. The first is a remote control-like device that allows users to listen to short stories related to an artwork; it is installed at the Carnegie Museum of Art in Pittsburgh (Berkovich et al. 2003). It is an audio system with a special speaker which delivers pinpointed audio and can be heard near the work of art.

Another PDA application has been tested at Genoa's Costa Aquarium (Bellotti et al. 2002). The basic elements of the interface are multimedia cards, each corresponding to a presentation subject such as a particular fish or a fish tank containing several species. Each multimedia card provides users with content. Touch-screen buttons allow control of content presentation and navigation between tanks.

Grinter et al. (2002) report on an interesting study about the SottoVoce system which was designed to promote a shared experience during a visit to a historic house. The system supports shared playing of audio content between pairs of visitors, each using a PDA. The paper reports interesting findings on how this technology helps to shape the experience in the museum (shared versus individual use of the device).

Multimedia guide literature also includes research concerning the development of architectures for context-aware applications. (Dey et al. 2001) present an interesting attempt to define the notion of context and introduce a conceptual model with a set of methods to help drive the design of context-aware applications. Their proposal is a computational framework to quicken the implementation and prototyping of context-aware applications.

Efstratiou et al. (2003) introduce a new platform to support the coordination of multiple adaptive applications. Coordination can be specified in terms of policies (they also present a formal language to define them) which allow adaptive (re)actions on a system-wide level to be described. For instance, it is possible to define the level of system intrusiveness, for example, whether to notify the user of system actions.

Seamless connection between mobile devices is a recent research issue. Krüger and colleagues focused on providing user-adapted seamless services in different situations. They worked on a route planning scenario where a user is supported by a central system while using three devices: a desktop route planner, an in-car navigation system, and a pedestrian navigation service running on a PDA (Krüger et al. 2004).[2]

Evaluation studies provide insights on both design and reimplementation of prototypes. In addition to previously cited works, the added value of systematic evaluation is shown in Bohnenberger et al. (2005), which reports on improvements brought to a mobile shopping guide after an iterative evaluation cycle. In particular, the authors focus on usability issues of the PDA interface with respect to the task to be accomplished (buy items in the minimum possible time) and on the accuracy of the system in supporting the user.

1.3 History of the System

At the beginning of the project, we stated the requirements of a mobile guide. Unlike many mobile devices (e.g., cell phones) our guide had to be *wake-up-and-use* since it is not meant to be used daily. This means it had to be intuitive and clear, with almost no need for explanation. Second, it had to be nonintrusive, that is, it could not interfere with a visitor's enjoyment of artwork. Third, we wanted to experiment with a new communication paradigm based on *delegation* and *affect.* In many "information-seeking" scenarios people typically look for information (think of Web queries with search engines). We consider the museum experience as something that has more to do with entertainment than with information seeking. The system's proactiveness in delivering an appropriate presentation at the right time is essential. Therefore, we devised interaction based on delegation: visitors do not ask for information about an artwork, they rather signal liking or disliking (that is affect towards the artwork and the information presented by the system) and, almost implicitly, request information from the system. This feedback from the visitor can be seen as a sort of nonverbal backchannel gesture that the system takes into account in selecting information for that specific user. This introduces the fourth requirement: the system had to be adaptive, that is, it had to provide personalized information according to the user profile built during the visit. We also wanted to experiment with affective interaction, believing it might improve system usability and acceptability.

In the design of the system, we kept in mind four fundamental adaptive dimensions which were also used for the evaluation phase:

[2] See Chap. 7 on seamless presentations across devices.

- Location awareness: the system initiates interaction when it detects the visitor at a given position. This feature is enabled by means of sensors located close to each work of art.
- Follow-up: the system arranges the following presentations on the fly according to feedback received from the visitor through the interface.
- Interest: the system selects content appropriate to (estimated) user interests.
- History: the system appropriately refers to previously seen items or points to artworks closely related to the one currently visited.

From the design requirements, we moved along iteratively, through quick prototyping and small evaluations. This drove the evolution of the system—both the graphical interface and the backend—to the final prototype, which is based on a *like-o-meter* widget and a shallow semantic network for dynamically modelling visitor interests. In this section, we shed more light on the steps in this evolution.

1.3.1 First Design

The first design is based on a two-button interface, as illustrated in Fig. 1.

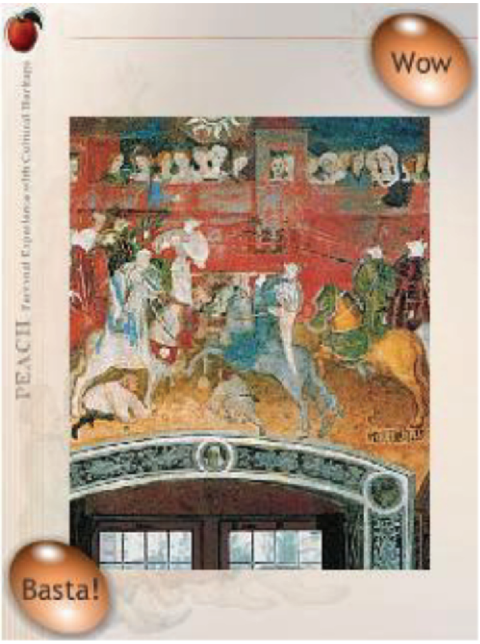

Fig. 1. The first prototype of the interface

Pressing the WOW button is meant to express a visitor's interest whenever she is impressed by a fresco or by a specific topic related to it. The BASTA! button, on the other hand, was to be used for lack of interest in current topic. As a side effect, the BASTA! button stops the current presentation. It is worth noting that a presentation can also be stopped by moving away from the current fresco to approach another one.[3] The central part of the screen was used to show a video presentation.

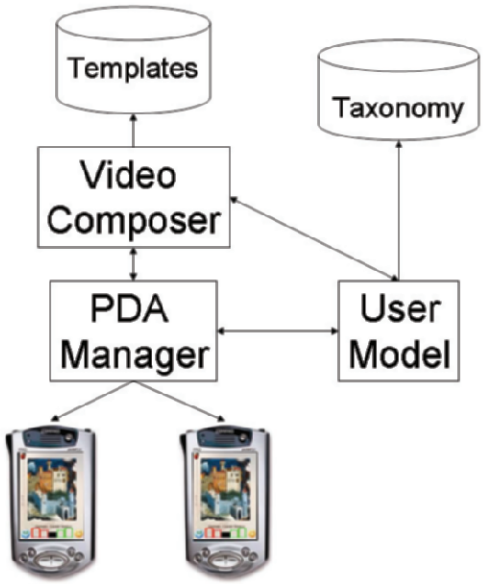

Fig. 2. Architecture underlying the first prototype

The underlying architecture that supports the first prototype consists of the following components (Fig. 2):

1. A video composer (VC) for dynamically composing presentations from a repository of templates according to the user interests stored in the user model.
2. A user interface manager (UI) for catching user location, interaction through buttons, and dispatching the presentations generated.
3. A user model for receiving the messages from the UI, for computing the current interest level of the visitor on each of the topics, and for propagating interest level according to a topic's taxonomy.

[3] This feature is "discovered" by the visitor during the visit.

4. A tree-based topic taxonomy which represents the contents of the pictures at three levels of abstraction (from specific content to abstract concepts such as "aristocratic leisure activities").

Templates, encoded in the XASCRIPT formalism, allow definition of a set of possible video documentaries from which user-tailored presentations are dynamically assembled (Rocchi and Zancanaro 2003). A template contains a set of instructions for image selection (or audio clips), and variable settings. By means of a merging mechanism, the system uses a single template to compose different video documentaries, conditioned by the user profile built by the user model (see Chap. 2).

1.3.2 Initial User Studies

Using the prototype described above, the first user study was set up in the real scenario, Torre Aquila, and included eight visitors. In the tower, we installed:

- A laptop, running the server side of the system.
- An access point, to allow wireless communication between devices.
- A PDA, running the interface shown in Fig. 1.
- Four infrared beacons, one for each fresco, to detect user position.

Users were "real" visitors, recruited at the entrance. They were given a short verbal introduction about the guide, followed by a real visit of four frescos (of eleven) exhibited. The experimenter observed the users during the visit. At the end of the visit, an informal interview was performed in order to assess the perception of the four adaptive dimensions: location, follow-up, interest, and history.

At the end of this evaluation cycle, both looking at interviews and considering experimenter observations, it was apparent that users did not clearly understand the graphical interface. In other words, during the experiments to investigate the effects of adaptivity on visitors, we found that the system was not usable. The WOW button was the source of many misunderstandings of the whole system. Sometimes it was pressed to initiate the interaction, although this is not needed at all.

To study usability and user perception of adaptivity in more depth, we resorted to an "action-protocol and retrospective-interview" qualitative study, targeting the expression of the affect and the delegation-of-control paradigm. The main difference of this methodology with respect to think-aloud is that the user does not provide her comments during the execution of the task, but later on, while she and the experimenter are watching a video recording of the interaction (Van Someren 1994).

The study was conducted on three subjects, in a room equipped with posters of the originals frescos, and with sensors to detect the positions of the subject with respect to the frescos. Although small, this is deemed to be a reasonable number of users for an initial investigation according to Nielsen (1993). The room was also equipped with two cameras to record both user behaviour and speech during the visit. The subjects performed a visit by using the guide; the study was limited to four frescos. At the end of the visit, each subject was interviewed by the experimenter while both were watching the video of the visit. The interview focused on the subject's understanding of the WOW button. The interview was recorded, providing important additional material for the research and design teams to discuss during the post-study phase. The results of this study revealed very interesting findings:

1. Loading the information at the beginning of each presentation takes few seconds, which was too long for visitors. In that amount of time, users get disoriented because they do not know what to expect. They do not understand their role with the system, and the WOW button is the only action they can perform during that time, probably in hope of getting information. The instructions did not prepare the users well for that situation.
2. At the end of the presentation, the system stops and shows a default screen shot, delegating the continuation of the visit to the user. This incoherence in the conceptual model confuses the user again, who presses the WOW to get some instructions but, instead, gets another presentation because the interest model was reinforced.
3. When all the content about a fresco was presented (including extended presentations retrieved by the user model) the system expects the user to move on. However, the user does not know the system status, therefore, she still expects something to occur. Again, the only available button is WOW.
4. The BASTA! button is interpreted just as a stop because it causes the system to stop the presentation. This is also incoherent with respect to the design guidelines, because the system should not enable to take an action, but just to express feelings (in this case "don't like").

In the end, the WOW button is often used as the resource of "last resort" to communicate with the system in case of problems. This shows that the intended conceptual model was not clear to the subject, and that the system often has incoherent or unexpected behaviour. In particular, the presentation should not abruptly stop. Rather, the user should be invited to move to another fresco. The system should give feedback about its own status, and inform users about its estimates of user interest; Kay (2001) calls this feature scrutability. It should skip uninteresting presentations, and focus on more interesting ones, or suggest moving to other frescos.

1.3.3 Second Redesign

Based on the results of the pilot study, we redefined the initial requirements for the new prototype:

1. The UI should clearly and intuitively enable the user to express her feelings towards the exhibits during the museum visit.
2. The UI should be coherent and consistent, reflecting the delegation of the control interaction paradigm on all four adaptivity dimensions.
3. The UI should be proactive in order to avoid user disorientation, even if users are told that the system tracks their position. For example, the system should signal when a new position is detected.
4. The UI should give visual feedback to the user, relating its understanding of user interest and its current status (such as preparing presentations for display), without disturbing user attention.
5. The information provided by the system must be structured differently, to allow different degrees of personalization.[4]
6. If the visitor does not express any feeling (that is, she never presses any button), she should receive a reasonable amount of information about the museum's exhibits.
7. Each presentation must have a title for display during the playing.

These requirements led to the prototyping of the second interface, shown in Fig. 3, which features a new widget (at the bottom), called the *like-o-meter*. It substitutes the two previous buttons and aims at better conveying the delegation paradigm. This widget allows the user to express her interest towards the current presentation, by moving the slider towards the smiley face (two degrees of liking), or state "I don't like it", by moving the slider towards the sad face on the left (two degrees of disliking). The presentation title appears close to the widget, helping the visitor to remember what she is "scoring". The feedback from the visitor is taken into account

[4] This requirement came from a strategic research decision and not from pilot study evidence.

by the system, which activates a propagation mechanism at the end of each presentation to update the interest model of the visitor.

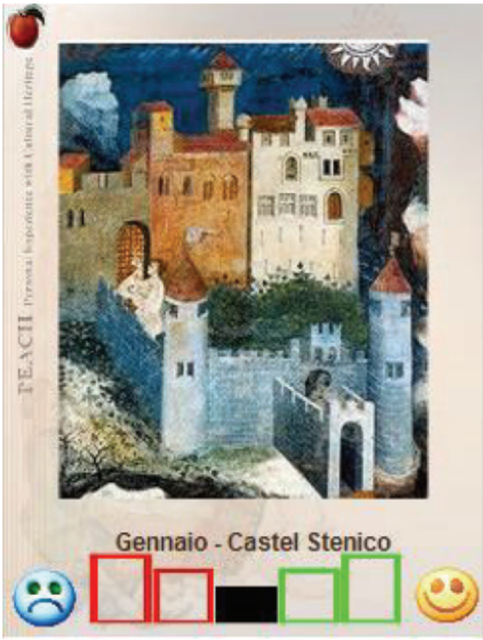

Fig. 3. The second interface prototype, based on the *like-o-meter*

The propagation is performed on a network of templates, as shown in Fig. 4. In fact, in this redesign, we also made modifications to the backend of the system. We decided to drop the taxonomy of topics, in favour of a content-based classification of the templates. Instead of using a user model, reasoning on the structure of the domain at different levels of abstractions, we wanted to experiment with an explicitly linked network of contents, classified on the basis of their communicative functions (see Sect. 1.4).

The template network is organized in nodes, each having an interest value that is zero at the beginning. The interest value assigned to each template ranges from –2, meaning current lack of interest or likely future lack of interest, to +2, meaning strong interest or likely future strong interest. The links between nodes are created by the author network. Each link is a shallow semantic relation which can be paraphrased as “related to”.

Nodes can be of five types:

1. Introduction: contains a general overview of an exhibit
2. Abstract: quickly describes a part of an exhibit
3. Content: extends the presentation of an abstract
4. Follow-up: describes general themes shared by two or more exhibits (e.g., hunting in the middle age)
5. Conclusion: tells the visitor that the presentation of an exhibit is over

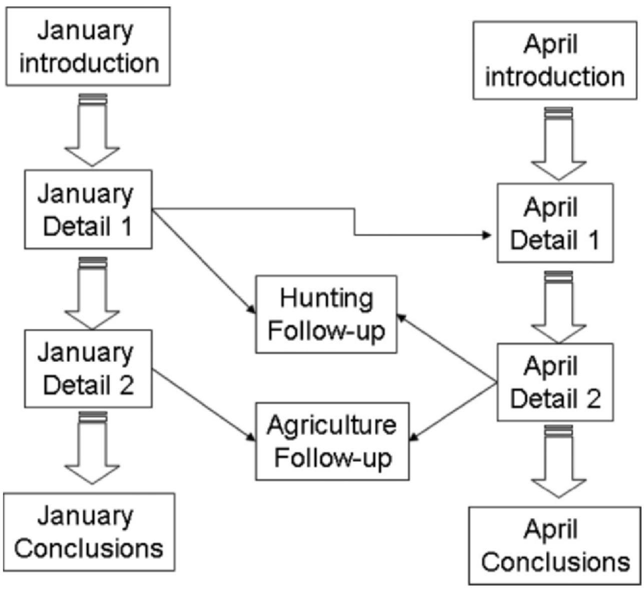

Fig. 4. An example of the template network

As feedback is received through the interface, the system updates the interest value of the current template and also propagates such information to its connected templates, according to the following dependency relations:

1. Introduction affects abstract: a positive or negative degree of interest, expressed when the system presents the general introduction to an exhibit, is propagated to all the abstracts pertaining to the same exhibit. The abstract is the basic information on an exhibit with respect to a certain topic.
2. Abstract affects content: the degree of interest towards the abstract updates the value of its related content (that is, a more detailed