EXPLOITING MOBILE DEVICES TO SUPPORT MUSEUM VISITS THROUGH MULTI-MODAL INTERFACES AND MULTI-DEVICE GAMES

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Abstract: Mobile devices are enabling innovative ways to enjoy museum settings. In particular, their multimodal interfaces can provide unobtrusive support while users are freely moving and new applications, such as games, can benefit from the combined availability of mobile and stationary devices. In this paper we report on our new solutions and experiences in the area of mobile support for museum visits.

1 INTRODUCTION

Seamless interoperability of intelligent computing environments and mobile devices is becoming more and more popular in various application domains. A potential application area is the so-called "intelligent guides". Several location-aware, context-aware and multi-modal prototypes have been developed since the beginning of ubiquitous computing in the early 90's, see for example (Oppermann and Specht, 2000).

In this paper, we present our recent solutions in this area, by extending a previous museum guide (Ciavarella and Paternò, 2004), which already supported graphical and vocal modalities and location detection through infrared beacons.

To this end, we have designed an interaction technique based on two important concepts:

i) it should not be intrusive on the user experience, by leaving the visual channel open to enjoy the artwork;
ii) it should be able to somehow directly interact with the available physical objects.

The first concept is motivated by previous analysis of museum visitors and how they perceive the support of computer-based devices. The results clearly indicated that the user would not be interested in spending much time understanding how the electronic guide works, especially because they will probably not visit the museum again. On the other hand, the information usually provided by museums regarding artworks is rather limited (e.g.: mainly short textual labels), which raises the need for additional support to be dynamically activated when something interesting is found during the visit. For this purpose, it would be useful for visitors to have the possibility of pointing at the artwork of interest and controlling audio information with small hand gestures while still looking at the artwork.

In addition, a museum visit is often an individual experience, even electronic guides and interactive kiosks are usually not designed to promote social interaction to increase user experience. In this context, games for mobile guides can provide an interesting and amusing way to enrich users interaction and promote their collaboration. The use of shared large displays can enable further functionality, such as presenting the visitors' position and different ways to represent individual and cooperative games exploiting the large screen.

The paper is structured in the following way: we first introduces related work in the area of mobile guides, then we describe the original Cicero guide and its main features. Next we discuss how we have extended it in order to support innovative interaction techniques through RFIDs and accellerometers. Then, we describe another extension, which provides the possibility of several games that can be played by multiple players using both mobile and fixed devices. Lastly, we draw some conclusions and provide indications for future work.

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2 RELATED WORK

The museum domain has raised an increasing interest regarding the support that can be provided to visitors through mobile devices. One of the first works in this area was the Hippie system (Oppermann and Specht, 2000), which located users via an IR system with beacons installed at the entrance of each section and emitters installed on the artworks. The GUIDE project (Cheverst et al., 2000) addresses visitors in outdoor environments supported through several WLANs. In our work, we focus on indoor visitors: it requires consideration of different solutions for supporting them. While such works provided a useful contribution in the area, we noticed that in the museum domain innovative interaction techniques were not yet investigated. They can be useful to improve user experience by making the interaction more natural.

Research on gesture interaction for mobile devices includes various types of interactions: measure and tilt, discrete gesture interaction and continuous gesture interaction.

Our study differs from related work since we extend the tilt interaction by associating tilt events with a few easy-to-use interaction commands for the museum guide, and combine such tilt interaction with other modalities, following a consistent interaction logic at different levels of the application.

Physical browsing (Valkkynen et al., 2003) allows users to select information through physical objects and can be implemented through a variety of tag-based techniques. Even mobile phones that can support it through RFIDs have started to appear on the market. However, we think that it needs to be augmented with other techniques in order to make museum visitors' interaction more complete and natural. To this end, we have selected the use of accelerometers able to detect tilt events, allowing users to easily select specific information regarding the artwork identified through physical pointing with small hand movements, so that the user visual channel can be mainly dedicated to looking at the artworks.

The area of mobile guide support has received a good deal of attention, see for example the Sotto Voce project (Grinter et al., 2002). In this paper we want to also present a novel solution able to exploit environments with stationary and mobile devices, equipped with large and small screens. There are various types of applications that exploit such environments (Paek et al., 2004):

- "jukebox" applications, use a shared screen as a limited resource shared among multiple users (see Pick-and-drop interaction paradigm);
- collaborative applications, allow multiple users to contribute to the achievement of a common goal).
- communicative applications, simplify communication among individuals, see Pebbles (Myers et al., 1998).
- "arena" applications, support competitive interactions among users.

CoCicero (Laurillau and Paternò, 2004) allows collaborative games and interaction among visitors: one feature is to individually solve games, thereby enabling parts of a shared game, and supporting a common goal. This new environment aims to support multi-user interaction and cooperation in the context of games for improving the learning of museum visitors.

3 CICERO

Our interaction technique for museum visitors has been applied to a previously existing application for mobile devices: Cicero (Ciavarella and Paternò, 2004). This is an application developed for the Marble Museum located in Carrara, Italy and provides visitors with a rich variety of multimedia (graphical, video, audio, …) information regarding the available artworks and related items (see Figure 1).

Figure 1: User in the Marble Museum with CICERO.

This application is also location-aware. This is implemented through a number of infrared beacons located on the entrance of each museum room. Each of them is composed of several infrared emitters and generates an identifier that can be automatically detected by the application, which thus knows what room the user is entering and immediately activates the corresponding map and vocal comments. This level of granularity regarding the location (the current room) was considered more flexible and useful than a finer granularity (artwork), which may raise some issues if it used to drive the automatic generation of the guide comments.

In addition to information regarding artworks, sections and the museum, the application is able to support some services such as showing the itinerary to get to a specific artwork from the current location. Most information is provided mainly vocally in order to allow visitors to freely look around and the visual interface is mainly used to show related videos, maps at different levels (museum, sections, rooms), and specific pieces of information.

4 THE SCAN AND TILT INTERACTION PARADIGM

Digital metadata on artwork facilitates electronic guides for museums (e.g. it is easier to arrange temporary exhibitions when metadata can be made available to electronic guides). Also, our concept of guide interaction potentially benefits from the fact that artwork metadata can be structured in a nested, tree-type structure.

The scan modality operates on a higher level (i.e. it can be used to choose the main element of interest), while the gesture modality enables operations between elements in the metadata structure (i.e. horizontal tilt allows navigating among pieces of information at the same level). These aspects make the interaction more immediate and potentially easier for visitors to orient themselves within the information presented by the device.

When a visitor enters a space, this is detected through the infrareds signals, and a map of the room is provided automatically.

A visitor then scans a RFID tag associated with an object by physical selection, and the object is highlighted graphically on the room map. That is, information on a mobile device is associated to an object in the physical environment. In the detailed data-view, navigation among different pieces of information can be done by tilting horizontally. Alternatively, when users enter a room and get information regarding it, they can use the tilt to identify/select different artworks in the room through simple horizontal tilts. Whenever a new artwork is selected, then the corresponding icon in the room map is highlighted and its name is vocally rendered. In order to access the corresponding information, a vertical tilt must then be performed. Note that the current interpretation of the tilt event can also be enabled/ disabled through a PDA button.

Figure 2: Example of scan and tilt interaction.

In general, the tilt interface (see Figure 2) follows a simple to learn pattern: horizontal tilts are used to navigate through different pieces of information at the same level or to start/stop some activity, vertical tilt down events are used to go down in the information hierarchy and access more detailed information, whereas vertical tilt up events are used to get up in the information hierarchy. Since there are different levels of information supported (the museum, the thematic sections, the artworks, and the information associated to specific artworks and its rendering,.), when a specific artwork is accessed, it is still possible to navigate by horizontal tilting to access voice control (to decrease/increase the volume), control the associated video (start/stop), and access information regarding the author.

The scan modality is used to orient users in a physical environment and to select data on a higher level. After summary information is provided on the mobile device, gesture modality is used to navigate between various views/levels of detail by tilting.

When users receive scan data through the RFID manager, it is communicated to the museum application, and when the device is tilted, the tilt manager feeds the tilt data to the application accordingly.

The gesture modality in our approach utilizes 2D acceleration sensor hardware from Ecertech. The sensor hardware is attached to an iPAQ PDA with Pocket PC operating system and can be used also in other Pocket PC PDAs and SmartPhones. The sensor produces signals that are interpreted as events (TiltLeft, TiltRight, TiltBackward, TiltForward) by the tilt manager-data processing module of the mobile device. User-generated tilt-based events can then be used to execute interactions (selection, navigation or activation) according to the user interface at hand.

The scan modality employs RFID technology by Socket Communications. The RFID reader (ISO 15693) is connected to the Compact Flash socket of a PDA. Artworks in the museum environment are equipped with RFID-tags containing identifiers of the given artwork. A user can obtain information related to a work of art by placing the device near the tag and having the data associated with the tag code passed to the guide application through the RFID reader hardware.

The first release of the software prototype uses a simple tilt monitoring algorithm based on static angle thresholds and taking into account the initial tilt angle of the device when the application starts. The tilt of both horizontal and vertical axes is measured every 1/10 second. These values are then compared to the original tilt measurement performed at application start-up time, and if a 15 degree threshold is exceeded for over 500ms in one of the axes, this is interpreted as the appropriate tilt gesture for that axis: 'forward', 'backward', 'left' or 'right'. Although the algorithm might be deemed as a simple solution, its usage has allowed us to obtain valuable preliminary good user feedback (see “Evaluation” section).

5 MULTI-USER INTERACTION THROUGH GAMES

As we introduced before, another extension of Cicero museum guide deals with allowing collaborative games and interaction among museum visitors. In CoCicero the objective is to individually solve games, thereby enabling parts of a shared game, and supporting a common goal. This environment aims to support multi-user interaction and cooperation in the context of games for improving the learning of museum visitors.

The environment supports both individual and cooperative games. Users are organised in groups. Each user is associated with a name and a colour. The environment supports five types of individual games (see Figure 3):

- The *quiz* is a question with some possible answers. For each right answer the user gets two points and one piece is removed from the shared enigma.
- In the *associations* games users must associate images with words, eg the author of an artwork, or the material of an artwork.
- In the *details* game an enlargement of a small detail of an image is shown. The player must guess which of the artwork images the detail belongs to.
- The *chronology* game requires the user to order chronologically the images of the artworks shown according to the creation date.
- In the *hidden word* game, the users have to guess a word: the number of characters composing the word is shown to help the user.

In all types of exercises, when the user solves the problem then points are increased and a piece is removed from the puzzle associated with the shared enigma. The social games such as the shared enigma are an important stimulus to cooperation.

The enigma is composed of a series of questions on a topic associated with the image hidden by the

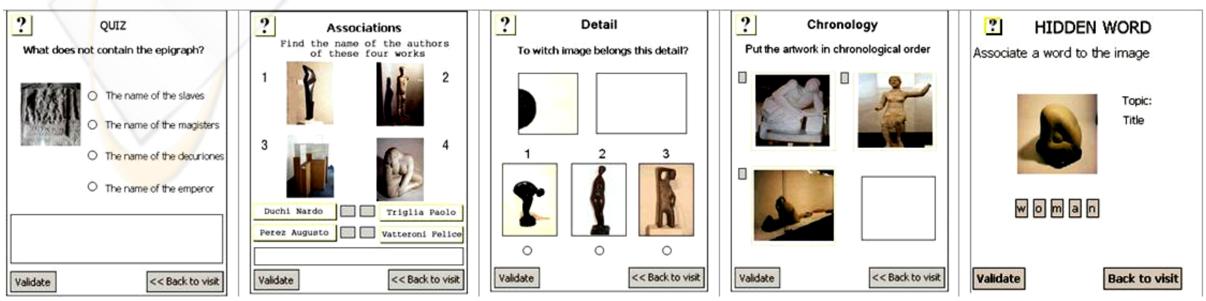

Figure 3: Five types of games supported.

puzzle. At any time a player can solve the shared enigma: for each correct answer, one piece is removed from the puzzle, and the group earns seven points. This favours numerous groups (the maximum is five members) because they can earn more points, and it is a stimulus to cooperate. When a member of the group answers the corresponding question, such question is no longer available also to the other players in the team. This stimulates an interaction among visitors so that they can first discuss the answer and agree on it. The PDA interface of the shared enigma has two parts: the first one shows the current player's scores and the hidden puzzle image, the second shows the questions (with possible answers).

One important feature of our solution is to support game applications exploiting both mobile and stationary devices. The typical scenario is users freely moving and interacting through the mobile device, who can also exploit a larger, shared screen of a stationary device when they are nearby. This improves user experience, otherwise limited to an individual mobile interaction, and also stimulates social interaction and communication with other players, although they may not know each other.

A larger shared screen extends the functionality of a mobile application enabling the possibility to present individual games differently, to share social games representations, and show the position of the other players in the group. Since a shared display has to go through several states, the structure of its layout and some parts of the interface (e.g.: date, time, number of connected players and list of users with associated scores) remain unchanged so as to avoid user disorientation. A game can be shown in two different modes, selectable through the PDA interface: normal and distributed. In the normal mode the PDA interface does not change while on the large screen a higher resolution image of the game is shown along with the player state. This representation is used to focus the attention of multiple users on a given game exploiting the screen size. In the distributed mode, the possible answers are shown only on the PDA, while the question and a higher resolution image are on the larger screen.

The result of the user answer is shown only on the PDA interface. In case of social games (e.g. the shared enigma) if only the PDA is used, the shared enigma interface visualises sequentially two presentations (the hidden image and the associated questions) on the PDA; if the shared screen is available, the hidden image is shown on it, while the questions are on the PDA (see Figure 4).

Providing an effective representation of players' position on the PDA is almost impossible, especially when they are in different rooms. Thus, the large shared screen is divided into sections, one for each player. Each part shows the name and the room where the player is located and a coloured circle shows the last work accessed through his/her PDA.

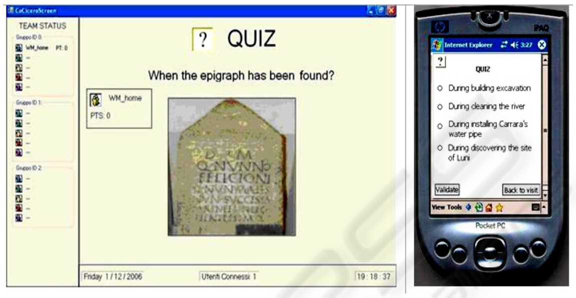

Figure 4: Example of game interface distribution.

5.1 Software Architecture

The main elements of the software architecture are the modules installed in the mobile devices, in the stationary device and the communication protocol designed for the environment. The PDA module is composed of four different layers, each providing the other layers with services according to specific interfaces. From the bottom they are:

- Core, which provides the basic mechanisms;
- Communication, implements the network services for sending/receiving messages;
- Visit, supports interactive access to museum info;
- Games, supports the interactive games.

In particular, the core implements data structures useful for the upper layers, e.g. support for configuration and help, and the XML parsers. It also contains the concurrency manager of IRDA signals (infrared signals used to detect when the user enters a room). The communication layer provides functionality used to update the information regarding the state of the players, to connect to shared stationary displays and to exchange information among palmtops, and therefore implements algorithms for managing sockets, messages, and group organisation. Such layer is exploited by the visit and game layers. The visit layer supports the presentation of the current room map and a set of interactive elements. Each artwork is associated with an icon identifying its type (sculpture, painting, picture, …), and positioned in the map according to its physical location. By selecting such icon, users can receive detailed information on the corresponding artwork. In addition, this part of the application allows users to receive help, access videos, change audio parameters, and obtain other info.

The games layer has been designed to extend the museum visit application. The artworks that have an associated game show an additional white icon with a “?” symbol, through which it is possible to access the associated game. If the game is solved correctly the icon turns green, otherwise it becomes red. In addition, an additional menu item enabling access to social games, such as the shared enigma, is available to the user, and the scores are shown in the top left corner. The games are defined through XML-based representations, so as to allow easy modifications and additions. The game layer exploits the parser implemented at the core level and the services provided by the communication layer to inform all players of the score updating.

The module associated with the stationary devices is structured into layers as a server:

- The *core*, provides basic data structures, a monitor to synchronize threads, and a parser.
- The *communication manager* receives and sends messages to the mobile devices, monitors messages in order to update their scores;
- The *UI manager* updates the information presented according to the messages received.

The system uses a peer-to-peer protocol, which has been designed for the target environment. The players and the associated PDAs can organise themselves in groups without the support of centralised entities through a distributed algorithm.

All the devices (both mobile and stationary) monitor a multicast group without the need to know the IP addresses of the other devices. When messages are received, the PDAs check whether they are the target devices: if so, they send the corresponding answer, otherwise the message is discarded. The connection with the fixed devices is performed through TCP by a dedicated socket in uni-directional manner (from the mobile devices to the stationary one). The responses from the fixed device are confirmation or failure messages, relevant for all players and are thus sent through the multicast group.

6 EVALUATION

We performed first evaluations of the extensions of the prototype we described in the previous sections The tests involved more than 10 people recruited in the institute community.

Before starting the exercise, users were instructed to read a short text about the application Then, a short description about the task that they were expected to carry out was provided. After carrying out the exercise, users were asked to fill in a questionnaire, which was divided into two parts. In the first part some general information was requested by the user (age, education level, level of expertise on using desktop/PDA systems, etc.). The second part was devoted to questions more specifically related to the exercise.

6.1 The Scan and Tilt

As far as the scan and tilt paradigm is concerned, users were asked to scroll a number of artworks belonging to a specific section (main window); then, they were expected to select one artwork (secondary window) and navigate through the different pieces of information available (e.g.: author, description, image, ...), to finally get back to the initial window in order to finish the exercise.

People involved in the tests reported to be, on average, quite expert in using desktop systems, but not particularly expert in using PDAs. Roughly half of them had already used a PDA before the exercise (7/12), only a few reported to have ever heard about scan and tilt interaction. On average they judged scan and tilt useful, with interesting potentialities.

The majority of them (8/12) reported some difficulties in performing the exercise. Only 2 reported no difficulty, while other 2 reported many difficulties. People that experienced difficulties, generally self-explained this fact saying that it could have been motivated by the novelty of the technique and their complete lack of experience with such an interaction technique.

As for the kind of difficulties encountered, there were aspects connected to the initial difficulty in using the technique and understand the tilt thresholds expected for activating the tilt event, but most of these problems diminished after the initial interaction phases. Vertical tilt was found to be the most difficult interaction, while horizontal tilt was found the easiest one for the majority of users. Almost all the users judged the application user interface to be clear (in a 1-5 scale, only one reported a value of 2, whereas the others reported 4 or 5). Users judged scan and tilt interaction fairly easy to use (on average, the mean value was 3 in a 1-5 scale) and in fact several of them pointed out that it is just a matter of time to get used to it. They judged that scan and tilt makes interaction slightly easier with respect to traditional graphical interfaces, even if they conceded that it would be quite difficult to use it without looking at the PDA. All in all the feedback was positive, even if we are aware that more empirical test is needed in order to draw definite conclusions.

6.2 Collaborative Games

As far as the collaborative games are concerned, users were asked first to access (and possibly solve) at least one example of each different type of game, then try to solve the shared enigma exploiting the large screen emulated on the screen of a desktop PC.

People involved in the tests reported to have, on average, a medium (3/5) experience in using PDAs. Although they judged the application especially suitable for schoolchildren, the general feedback about the application was very good: in a 1-5 scale, the games were judged amusing (4), intuitive (3.9), helping the learning process (4.2), and successful in pushing people collaborate and socialise. The UI of individual games was rated good (4,3/5), as well as the way in which the functionality was split between the PDA and the large screen (4.7/5); also the UI supporting such splitting was rated very good (4,8/5). Testers were also asked to report the games they liked most and those they appreciated less: the detail game collected the highest number of positive feedbacks (it was not surprising as it was the game which enabled the user to select the answer from a very limited set (3) of possible answers, thus with a good probability of success even with a limited knowledge about the artworks). Also not surprisingly, the hidden word was the game users liked less, self-explained by them by the fact that this game is more difficult as it required more knowledge since it is a quite open question (only the length of the answer is disclosed to the user) and it also requires the user to enter a word (and text editing is not very easy on a PDA, especially for users with little dexterity with such devices). All agreed that the large screen facilitates collaboration.

7 CONCLUSIONS

We have reported on recent experiences in exploiting mobile technologies for supporting museum visitors. They provide useful indications about important aspects to consider: multimodal interfaces, including use of RFID technologies and games in multi-device environments able to exploit both fixed and stationary devices.

Future work will be dedicated to identifying new ways for promoting socialization and cooperation between visitors. Further work is also planned for improving the algorithm that manages the scan-and-tilt interaction paradigm, in order to enable a more natural interaction with the device.

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