An Environment to Support Multi-User Interaction and Cooperation for Improving Museum Visits through Games

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ABSTRACT
The availability of mobile and stationary devices opens up new challenges to support users in several contexts. Here we present a multi-device environment to support cooperation among museum visitors through games. In particular, we present a design and the associated implementation for using a combination of PDAs and public displays to enhance the learning experience in a museum setting by using game playing interactions. The basic assumption is to use the mobile devices for individual game play, and the situated displays for synchronized public views of shared game play; the individual game play contributes to the shared game.

Categories and Subject Descriptors
H.5.M [**Information interfaces and presentation**].

General Terms
Design, Experimentation, Human Factors, Languages

Keywords
Mobile guides, collaborative games, Multi-device environments, Museum applications.

1. INTRODUCTION
Current technological trends are producing a wide availability of multi-device environments, characterised by the presence of both mobile and stationary devices. The complementarity of the features of such platforms opens up interesting and novel applications: fixed devices usually have more powerful processing capabilities and larger screens, but fixed location, while mobile devices enable user mobility but have limited processing and interaction resources. Such multi-device environments can be exploited even in multi-user applications, where users can freely move about but still exploit nearby fixed device resources in various ways.

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In the last decade, mobile museum guides have stimulated a good deal of work (see for example [1][6][13]). A museum visit is often an individual experience, even electronic guides and interactive kiosks are not usually 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' interactions and promote their collaboration. Museum co-visiting has been considered in a number of projects. The Sotto Voce project [9], developed at Xerox Parc, is a mobile companion, based on the iPaq technology, that provides audio content of artwork descriptions and acts as an audio media space between visitors, and thereby offers a mean for awareness and sociability. The authors have identified four kinds of activities: (i) shared listening, in order to promote interaction and communication between companions; (ii) independent use, in order to enable temporarily or entirely the switching off of the shared listening, in particular when visitors do not want to engage in social interactions; (iii) following, when a companion is in charge of leading, implicitly or explicitly, the tour; (iv) checking in, which is a short activity, to maintain and update the shared context. The City project [5], part of the Equator project, takes place at the Lighthouse museum in Glasgow, which is dedicated to the work of the designer Mackintosh. The system considers three kinds of technologies: (i) for the real visit, the visitor uses a PDA equipped with headphones and microphone and with an ultrasonic location system; (ii) for the virtual reality visit, a visitor navigates in a 3D representation of the museum; (iii) for the Web visit, a visitor navigates using a standard browser with Java applets. With this system, visitors are able to share their museum experience and navigate jointly through mixed realities: the Web, the virtual and physical reality. Information is provided about each visitor location and orientation. In addition, they may communicate through audio channels. The authors have observed that voice interaction, location and orientation awareness, and mutual visibility are essential to the success of museum co-visiting between remote users. In contrast to the Equator City project, we consider "physical" visitors moving in the real museum while they consider a mixed visit combining the real museum and a virtual representation of the museum (in a 3D representation or through a Web site). Some of the existing projects consider pure collaborative virtual visits as Web co-visiting, such as the Van Gogh museum. The authors of the Equator city project, as in the Sotto voce project, have noted that information about location and orientation of the companions

(checking in task) is essential in a cooperative visit in order to maintain group awareness. This point has been considered in our project, as detailed in the next sections: visitors are able to check for their companion and are aware about the state of the cooperative game. VeGame [3] is another project that uses mobile technology, in this case to explore the city of Venice and to learn about its history and its architecture through games based on observation, reflection and action (e.g. video games). The system enables wireless communication but, due to limited bandwith, communication between two peer PDAs is realised for real-time exchanges as in video games. Visitors may play in teams against each others, and the only goal is to obtain the best score. In addition, each team can have multiple members but only one PDA. Firstly, the collaboration is loose, because the high score is the unique objective and, considering our project, the visitors do not have to engage in a real cooperation such as in a treasure hunt. Secondly, inside a team, the collaboration is only face-to-face regarding a "single-user" application: the system does not provide any means to support the collaboration.

In addition, the use of large shared displays can enable further functionality [2][8], such as presenting the visitors' position and different ways to represent individual and cooperative games exploiting the large screen. To this end, we have extended Cicero [7], an electronic mobile assistant providing information on the available artworks. In this paper we want to 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 [11]:

- "jukebox" applications, use a shared screen as a limited resource shared among multiple users (see Pick-and-drop [15]);
- collaborative applications, allow multiple users to contribute to the achievement of a common goal (see for example Geney[8], OpenTrek[16]).
- communicative applications, simplify communication among individuals (see for example [8]).
- "arena" applications, support competitive interactions among users (see Pirates! [4]).

CoCicero [10] 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. We present a new environment aiming to support multi-user interaction and cooperation in the context of games for improving museum visitor learning. The goal is to make the museum visits more interactive and stimulate learning of related concepts. To this end, the proposed environment provides information about the user' s location in the museum, as well as ways to exhibit and test knowledge learnt about the artworks in the museum during the visit. In addition to the individual games, it also enables the individual museum visitors to group and play as teams, collecting scores by knowing the right answers to the posed questions.

In the paper, we first describe the types of games designed and implemented, and the underlying software architecture. Then, we show how multi-device environments are exploited to improve the games, in particular regarding the social aspects, and briefly report on first user experiences. Lastly, we draw some conclusions and provide indications for future work.

Figure 1. User in the Marble Museum with mobile guide.

2. BACKGROUND

Our interactive environment for museum visitors has been applied to a previously existing application for mobile devices: Cicero [7]. This is an application developed for the Marble Museum located in Carrara, Italy, and provides visitors (see Figure 1) with a rich variety of multimedia (graphical, video, audio, …) information regarding the available artworks and related items. The application provides several levels of information regarding the museum and its artworks (e.g.: museum level, sections' level, artworks'level), as shown in Figure 2.

Figure 2. Two screenshots of the Cicero guide.

This application is also location-aware. This is implemented through a number of infrared beacons located at 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 which room the user is entering and immediately activates the corresponding map and vocal comments. This level of granularity regarding identification of the user 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.

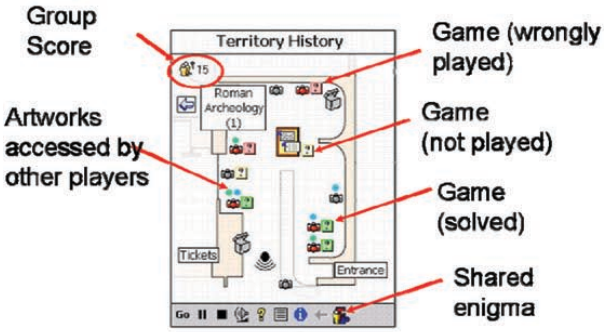

Figure 3. The cooperative support for games in CoCicero.

Figure 3 illustrates how the virtual guide has been extended to support games in multi-user environments and the related aspects. Visitors are divided into teams and players gain further points for their teams by solving problems in individual games shown on the PDA. The total amount of points gained by the team is visualised in the top-left corner of the user interface. Not all the artworks have an associated game: if a game is available, a "?" icon is shown beside the icon representing the artwork. The "?" icon is displayed in different status/colours, each colour provides further information about whether the user has visited the game and correctly solved it. Initially, the "?" icon is white; as soon as the user visits the game and correctly solves it, the icon turns green; a question answered incorrectly is represented by a red "?" icon. In addition, the application provides information on artworks accessed by the other players. Lastly, under the main panel there is a menu through which it is possible to trigger further actions, for instance access to a shared game.

3. THE GAMES

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 4):

- The quiz is a multiple choice question.
- In the associations games, users must associate images with an associated aspect, e.g. 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 date of execution.
- 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.

The social games are an important stimulus to cooperation. In particular, the shared enigma is composed of a series of questions on a topic associated with an image of an artwork hidden by an overlaid jigsaw puzzle. When a player solves one of the individual games described above, one piece in the puzzle is removed to expose the underlying section of the image and facilitate answering the main question. Solving each individual game earns the group seven points. Our goal in the design of the social game is to stimulate interaction and cooperation among players, who together must find the answers to the various questions making up the shared enigma. This favours large-size groups (the maximum is five members), since they can earn more points, and is a stimulus to cooperate. When a member of the group answers one of the enigma questions, that question is no longer available to the other players of the team. This stimulates an interaction among visitors so that they can first discuss about the solution and agree on it before answering the question. The PDA interface of the shared enigma has two parts (see Figure 5): the first one shows the current players' scores and the hidden puzzle image, the second shows the questions (with possible answers).

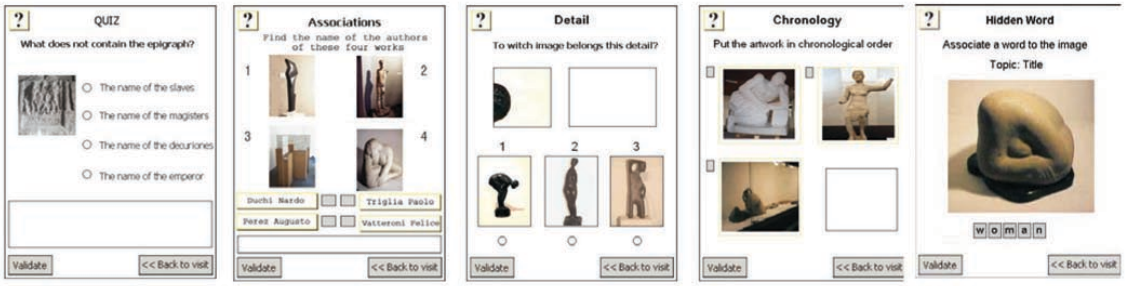

Figure 4: The five types of individual games supported in CoCicero.

4. GAMES IN MULTI-DEVICE ENVIRONMENTS

The main 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 (which can be considered a situated display) when they are nearby. Shared screens connected to stationary systems can increase social interaction and improve user experience, otherwise limited to individual interaction with a mobile device, and also stimulates social interaction and communication with other players, though 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 game representations, and show the positions of the other players in the group.

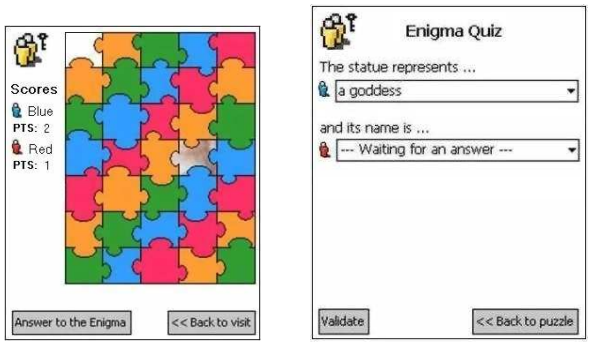

Figure 5. The shared enigma visualized on the PDA.

Each shared display can be in different states:

- IDLE: inactive state, the display shows a message informing the availability of the screen.
- ACTIVE: indicates that one player has taken control of the display, which shows the name and group of such player.
- SEARCH: the display shows the last artwork accessed by the players of a group and their scores.
- GAME: the display shows one individual game.
- SOCIAL GAME: the display shows the state of one social game.

Since a shared display has to go through several states the structure of its layout and some parts of the interface remain unchanged in order to avoid user disorientation. Such permanent part of the user interface provides information such as date, time, number of connected players at the bottom, and a list of users and associated scores on the left panel (see Figure 6). The screen centre shows the state of the shared screen. 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 (see Figure 7). This representation is used to focus the attention of multiple users on a given game exploiting the screen size. In the distributed representation, the game interface is split into two parts. The answer choices are shown only on the PDA interface, while the question and higher resolution images are shown on the larger screen (see Figure 8). The result of the user answer is shown only on the PDA interface.

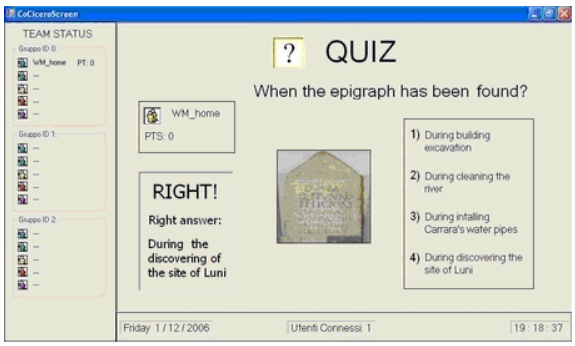

Figure 6: A game shown in the shared display in normal mode.

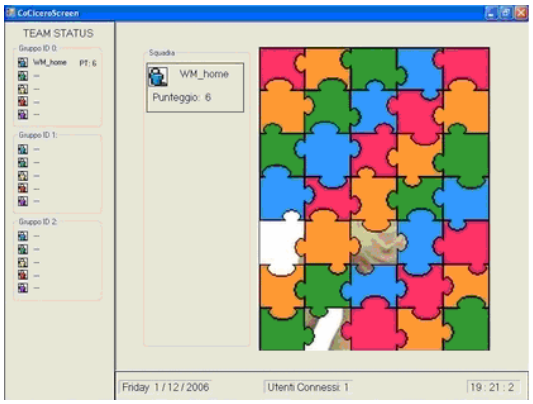

Figure 7: Visualising the enigma on the shared display.

In case of social games (e.g. the shared enigma), the shared screen is used differently. For example, if only the PDA is used, the shared enigma interface is composed of two presentations visualised sequentially: the hidden image and the associated questions) on the PDA. If the larger shared screen is available then the hidden image is shown on it (see Figure 8), while the answers are presented on the PDA user interface.

Providing an effective representation of players' position on the PDA is very difficult, 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 (see Figure 9).

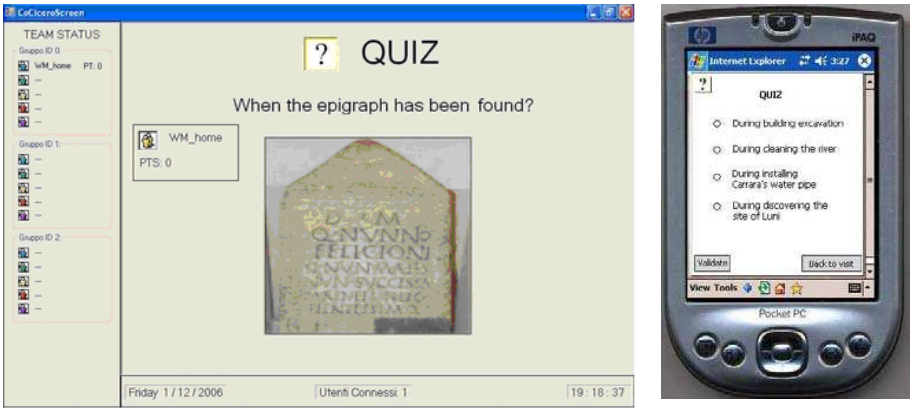

Figure 8: Example of game distributed mode: large screen (left part); PDA (right part).

5. SOFTWARE ARCHITECTURE

The main elements of the software architecture are the modules in the PDAs, in the stationary device and the communication protocol of the environment. The PDA module is composed of four layers, each one provides the others with services.

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. This is the layer that associates the artworks that have a connected game with an additional white icon with a "?" symbol, through which it is possible to access the 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, 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:

- 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: the players and associated PDAs can organise themselves in groups without the need 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 a message is received, the PDAs check if it is addressed to them: in the positive case they send an answer otherwise the message is discarded. The communication 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/failure messages, relevant for all players and then sent through the multicast group.

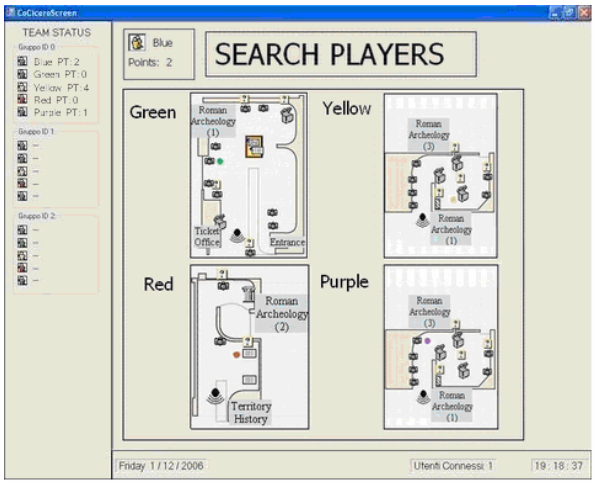

Figure 9: Example of visualization of players' positions.

6. EVALUATION

We performed a first evaluation of our prototype supporting multi-device and multi-user games. The test involved eleven people with an average age of 37 years, almost all with high education level (laurea degree). Users first read a short introduction about the gaming museum application and were also instructed about the tasks they were expected to carry out: 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. Afterwards they had to fill in a questionnaire.

People involved in the tests reported to have, on average, a medium (M=3.09; SD=1.64) 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 (where 1 represents the worst score and 5 the best one), the games were judged amusing (M=4; SD=0.89), intuitive (M=3.9; SD=1.13), helping the learning process (M=4.18; SD=0.6), and successful in pushing people collaborate and socialise. The UI of individual games was rated good (M=4.27;SD=0.64), as well as the way in which the functionality was split between the PDA and the large screen (M=4.72; SD=0.46); also the way in which the UI was split between the large screen and the PDA was rated very good (M=4.81; SD=0.4). While the kind of division between the two devices was judged effective, some users suggested to improve on the user interface how the action for triggering the splitting is currently supported on the PDA. Especially the functionality representation and the corresponding feedback were considered improvable. Indeed, a few of them noticed that, especially when the splitting is used for the first time, they just did not immediately understand what effect they were going to generate in the two devices involved in the interface splitting. A more significant feedback message provided to the user was suggested as possible improvement.

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. 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 (11/11) agreed that the large screen facilitates collaboration.

7. CONCLUSIONS AND FUTURE WORK

In this paper we described an environment supporting cooperation among museum visitors through games accessible by both mobile and fixed devices. We have described how the games for making more interactive and interesting the user experience have been designed in the context of a museum application. While a first user test has already been carried out we plan to gather further empirical feedback in the near future to investigate whether the multi-user and multi-device interfaces can be further improved.

Future work will be dedicated to implementing further mechanisms to provide real-time feedback of the activities performed by other visitors and identifying new ways for promoting socialization and cooperation between museum visitors, which are able to exploit the possibilities opened up by current technological advances.

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