

# A generic platform supporting museum co-visits using mobile devices

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## Abstract

The goal of this work is to provide tools that promote social interactions between mobile visitors through cooperative and educational games. In this paper, we describe how to support collaborative learning in museum visits and show an example application based on mobile palmtop systems. To this end, we have developed an interactive guide that is able to support collaborative and independent activities, and offer context-aware content.

## 1 Introduction

The wide dissemination of mobile technologies, such as cell phones or handheld personal digital assistants (PDAs), offers a good opportunity to get groupware applications out of the laboratories and develop new kinds of groupware applications which are no longer reserved for professionals and desktop computers. Mobile devices are becoming real social media, particularly in terms of communication. Such technologies are means to explore collaborative activities and can move groupware applications to public settings, such as museums.

The museum visit is usually an individual experience. Furthermore, electronic guides or interactive systems in museums are not designed to promote social interaction among visitors. However, the museum experience,

according to Falk and Dierking (Falk 2000), is influenced by the social context, which includes interactions between visitors. In addition, many studies have highlighted the fact that interactions with the exhibit, as well as communication and social interaction between visitors are also key points of a successful learning environment (Hindmarsh 2001, Leinhardt 2002).

The research on social interaction and collaboration using new mobile technologies is quite recent. In addition, there has been a change in the design of museum exhibitions in an increasing number of projects: little by little, the museum experience is considered as a collaborative activity and, more and more, museums are designed to support and encourage group interactions.

In this work, our goal is to promote interaction and communication between visitors through cooperative and interactive educational games, based on sharing, and using handheld PDAs. In this context, museum interactive systems are embedded in an electronic companion rather than being static fixtures in the museum. In addition, interactivity is considered at the visit level and not only at the artwork level: visitors are able to pace the visit and interact in the museum according to their desires. Furthermore, educational games are an interesting and entertaining way to initiate and promote collaboration between visitors. For example, the ghost ship project (Hinmarsh 2002) shows that playing and exploring artwork may help visitors to initiate collaboration. However, in this project, the ghost ship is a single interactive artwork and the approach should be extended to all the artworks in the museum.

In order to obtain a new solution, we have developed and deployed an interactive system, the portable Cicero, dedicated to supporting the visit of the Marble Museum of Carrara. This system enables communication, sharing

and collaboration among visitors, and also offers context-aware and personalized content. In the rest of the paper, we detail the main ideas of this project and provide a short review of related work. We then introduce our approach to support co-visiting in museum environments through PDAs. In the second part, we describe our system, the portable Cicero system. In the third part, we detail the software implementation of the application. Lastly, the results of a first evaluation are discussed.

## **2 Museum Co-Visiting**

Museum co-visiting has been considered in a number of projects. The Sotto Voce project (Grinter 2002), 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, which offers a mean for awareness and sociability. The authors have identified four kinds of activity: (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 social interactions; (iii) following, when a companion is in charge of driving, implicitly or explicitly, the tour; (iv) checking in, which is a short activity, to maintain and update the shared context.

The city project (Brown 2003), part of the Equator project, takes place at the lighthouse (Lighthouse museum) in Glasgow, a museum dedicated to the work of the designer Mackintosh. The system considers three kinds of technology: (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 visit 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.

The ghost ship project (Hindmarsh 2002), compared to the previous projects, is more oriented to an artistic experience of the museum co-visiting. The goal of this work is to analyze and consider informal and social interactions between visitors through video interaction recordings. The ghost ship installation is a dedicated room of the SOFA exhibition containing a wood painted ship, wooden figures, a simulated desk and an "inside the ship" area. Some of the ship portholes are video portholes which record and show visitor's behaviours and interactions with the ship. In addition, microphones capture visitor comments about their actions and about what they can see on the video portholes. The authors observed that the ghost ship helps visitors to break the ice more easily and to play with and explore collaboratively the ship.

Compared 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 (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 section: visitors are able to check for their companion and are aware about the state of the cooperative game.

VeGame (Bellotti 2003a) is another project that uses on mobile technology 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 a wireless communication but, due to a limited bandwidth, a 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 have the best score. In addition, each team can have multiple members but only one PDA. Firstly, there is a loosely collaboration because the high score is the unique objective and, considering our project, the visitors do not have to engage a real cooperation such as in a treasure hunt. Secondly, inside a team, the collaboration is only a face-to-face collaboration around a "single-user" application: the system does not provide any means to support the collaboration.

The history hunt project (Fraser 2003) has been carried out at the historical Nottingham Castle Museum. In this project, the authors have considered two kinds of activities: searching the castle for objects or traces of the past based on written clues on a paper tagged with an RFID distributed to visitors at the entrance. When visitors with the paper approach an interactive display, they are provided with additional information about the object or the trace described on the paper (still based on the RFID). We also base our approach on the treasure hunt metaphor. However, in history hunt project, collaboration between visitors occurs only when they are around the

interactive displays. On the contrary, in our approach, collaboration is supported throughout the tour by the mobile devices because visitors have a common goal, which is to solve a shared enigma.

### **3 The Cicero Project**

In this section, we describe the Cicero project for co-visiting at the Marble museum. The project is an extension of the original Cicero project introduced in the first paragraph.

#### **3.1 The original project**

The Cicero project (Ciavarella 2003) is originally an electronic companion, a single-user application that provides context-aware information about the artworks inside the museum. The application has been developed on iPaq PDAs with windows CE. In the design of the user interface, three types of tasks that users can perform in the context were considered:

- Orientation within the museum, for this purpose three levels of spatial information are provided: a museum map, a section map, and, for each physical environment composing the section, a map with icons indicating the main pieces of work available in the room and their location, as shown in figure 1. By selecting such icons the picture of the related element is displayed along with some basic information and the corresponding audio description is activated. The purpose of the picture is not to show the details of the work of art (that is supposed to be in front of the user), but to allow users to check that the information they are receiving regards the work that they are viewing. Through the use of infrareds beacons located on the top of each door the system is able to automatically detect each change of environment and activate the corresponding information.
- Control of the user interface, for example, to change the volume of the audio comments, to stop and start them, and to move through the various levels of detail of the museum description;
- Access to museum information, also this is provided at different abstraction levels (museum, section, physical environment, single work).

At any time the application is able to highlight where the users are in the museum area, assuming they are in the same room as the works last selected (see for example figure 1). The orientation information is triggered by selecting the “i” button on the bottom menubar that appears when the map of a physical environment is.

### **3.2 Collaborative Cicero project**

Cooperative visit, through educational games, as explained in the introduction and highlighted by the authors of the ghost ship project, is an interesting way to promote co-visiting and to engage visitors to share their museum experience. In addition, it may also preserve the individual aspects of the museum experience as highlighted by the authors of the Sotto voce project. However, audio sharing, as described and implemented in Xerox's project, may lead too much to a passive collaboration between companions such as the following or checking in tasks.

In this project, we consider two kinds of cooperative games: one to support explicitly cooperation and sharing; and one to support implicitly cooperation through individual activities. The first kind of cooperative game is similar to enigma or treasure hunt games: visitors have to gather clues and to solve cooperatively enigmas in order to find the solution and to find a particular artwork in the museum. This game needs visitors to share and to debate about what they have seen and learned during the visit. The second kind is a collection of educational games to discover the museum, at the individual level, all along the visit and to gather clues. Indeed, solving an individual game would provide clues to solve the shared enigma (solving a puzzle and answering to a quiz) and would provide awareness information about each visitor's activity. In addition, each visitor can pace its own visit: the group interaction is not highly coupled and the system supports mixed synchronous

and asynchronous modes. A scenario is provided at the end of the next section, in order to illustrate both kinds of games and how explicit and implicit collaboration is supported.

During the visit, at any time, visitors can use the museum map and the peripheral information about other visitors in order to share their clues and try to solve the shared enigma. In addition, visitors are able to submit solutions, which are validated when visitors need to meet each other and to discuss about the solution. However, in order to stimulate visitors to play with our interactive electronic guide, their names appear in the fame list in function of the number of points accumulated during the visit: if they cooperate a lot, they receive a proportional number of points.

### **User interface design**

Cooperative visit, through educational games, as explained in the introduction and highlighted by the authors of the ghost ship project, is an interesting way to promote co-visiting and to engage visitors to share their museum experience. In addition, it may also preserve the individual aspects of the museum experience.

In this project, we consider two kinds of cooperative games: one to explicitly support cooperation and sharing; and one to implicitly support cooperation through individual activities. The first kind of cooperative game is similar to enigmas or treasure hunts: visitors have to gather clues and cooperatively solve riddles in order to find the solution and find a particular artwork in the museum. This game requires that visitors share and discuss what they have seen and learnt during the visit. The second kind is a collection of educational games to help the visitors discover the museum individually throughout the visit and to gather clues. In fact, solving an individual game would provide

clues to solve the shared enigma (solving a puzzle and answering a quiz) and would provide awareness information about each visitor's activity. In addition, each visitor can pace its own visit: the group interaction is not highly coupled and the system supports mixed synchronous and asynchronous modes. A scenario is provided at the end of the section, in order to illustrate both kinds of games and how explicit and implicit collaboration is supported.

During the visit, at any time, visitors can use the museum map and the peripheral information about other visitors in order to share their clues and try to solve the shared enigma.

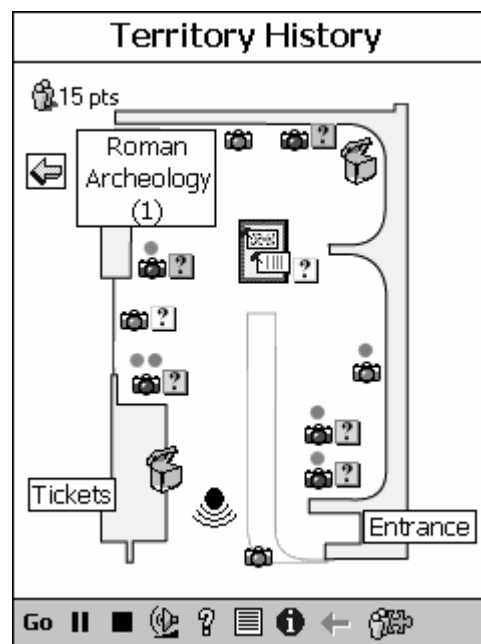



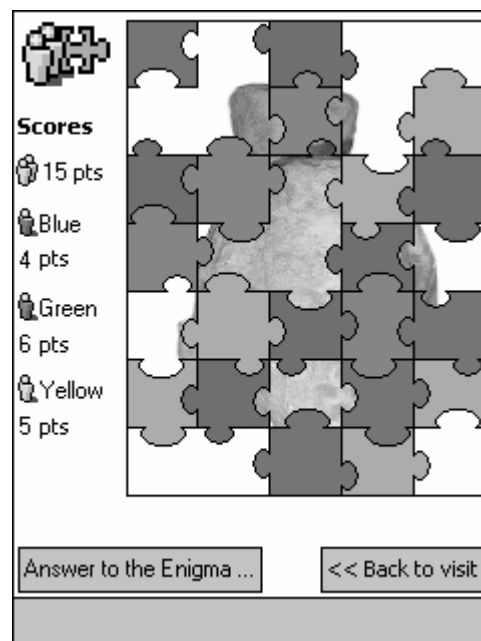


Figure 1. Navigation in the museum.

Designing a user interface in the context of the museum visit is not an easy task because that kind of software will be used only once by a visitor for one or two hours: the interface must be highly intuitive and affordable at first sight. It is, in one sense, a throw-away interface.

For this reason, we have tried to avoid a cognitive and visual overload of the new user interface, and we added only few icons, as shown in figure 1, in order to provide information about other users and the group activity, as well as about the available games. In the new interface, visitors are identified by their name and by a coloured bullet. In addition, coloured bullets ●● indicate what items had been seen by other visitors. An icon representing a  symbol indicates that an interactive game is associated with the related artwork, which had not been already solved. The following icon  15 pts, representing two little men, indicates the current score of the group. Finally, a click on the button  in the command bar, at the bottom of the screen and representing two little men and a piece of jigsaw, leads to the shared enigma screen described below.



**Figure 2. Shared enigma.**

In figure 2, we present an example of shared enigma: the goal is to find which artwork is hidden by puzzle pieces and to answer a quiz about this artwork. Each time a visitor finds a clue for the shared enigma, a puzzle piece is

removed and a piece of information about the artwork is made available. On the left part of the screen, the system indicates the current score and how many points each visitor has earned. In addition, visitors are able to answer questions about this artwork even if there are still puzzle pieces hiding parts of the image. At any time, the visitors can decide together to provide and validate a common answer to solve the shared enigma, based on the set of clues gathered during the visit. To illustrate this, let us consider the following scenario: Fabio (blue player), Yann (green player) and Carmine (yellow player) are visiting the Marble Museum and have decided to play together during the visit; the goal of the shared enigma is to find the artwork representing the statue of goddess Luni and to answer some questions about it, such as “who was Luni ?” (a goddess, protecting the colony of Luni, living near the town of Carrara).

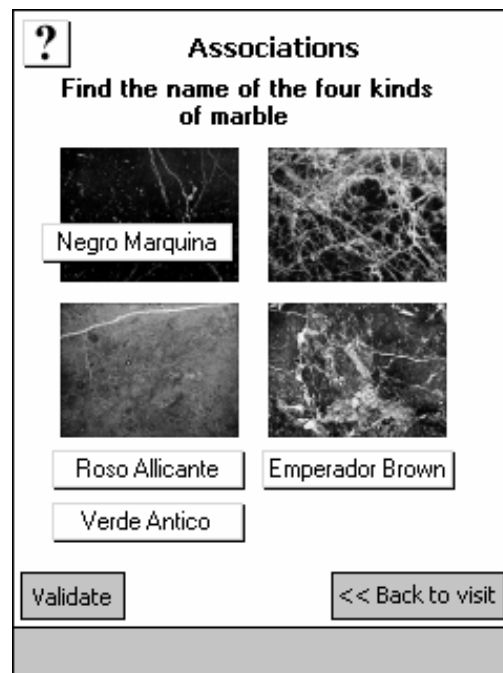



Figure 3. quiz game.

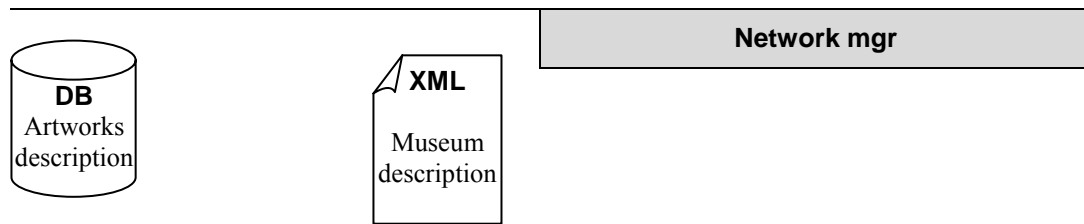
During the visit, Fabio is playing some educational games. For example, as shown in figure 3, one is to associate a type of marble with the right picture; another one is to play with letters in order to find the author of Vicarius' epigraph. Fabio has solved these games and has gained two clues that are automatically shared with Yann and Carmine: two pieces of information about the statue ("it represents a goddess" and "she was the protector of a colony"). In addition, two puzzle pieces, as shown in figure 2, are removed and the middle part of the statue is now visible. At that point, Yann and Carmine are aware that new clues have been found, as indicated by the "two little men" icon  15 pts, which is updated to indicate the new score, as shown in figure 1. Yann has found which artwork is hidden by the puzzle using the clues discovered by Fabio, but the questions still remain unsolved. Yann asks Fabio and Carmine if they have any idea. Based on the clues, they discovered that the sculpture represents a goddess, protector the colony of Luni: the shared enigma is solved.

#### 4 Software implementation

In this section, we describe how the system has been implemented. The first paragraph details the software architecture and its main components. In the second paragraph, we focus on the museum rendering engine component. The third paragraph deals with the implementation of the collaborative part of the application.

##### 4.1 Software architecture

<b>Multi User Interface</b>			
<b>Single User Interface</b>			
<b>Museum section rendering engine</b>	<b>Other UIs</b>	<b>Shared Enigma</b>	<b>Educational games</b>
<b>Functional Core components</b>			
<b>DB Mgr</b>	<b>Infrared detection</b>	<b>XML Parser</b>	<b>Concurrency mgr</b>



**Figure 4. Main software components of the Cicero project.**

As in the original project, the single-user and the collaborative version of the Cicero system are implemented in C++ on an iPaq, using IRDA sensors for location detection and a wireless network for communication between PDAs.

As shown in figure 4, at the user interface level, two kinds of components have been developed:

- The single-user part of the user-interface which is based on a major component responsible for the rendering of the museum sections and for the interactions with the artworks. This component is also based on three software components of the functional core: a database manager which sends queries to a database that contains details about the museum artworks; an infrared detector which locates the user in the museum and updates the current section automatically; an XML parser component that creates data structures representing the organization of the museum sections. In order to provide code flexibility and modularity, the description of the museum and the location of the artwork icons as well as the icons for collaboration are described in a separated XML document. Lastly, this part manages also additional user interface screens.
- The collaborative part of the user interface is based on the single-user part and on dedicated components such as the one which manages the shared enigmas and those that manage educational games. These

components are based on two components that are responsible for the management of the network communications and the concurrency control. Furthermore, the educational games have been developed as a plug-in loaded at runtime.

#### **4.2 Museum section rendering engine**

The museum section rendering engine is a keystone of the Cicero application. Indeed, the coexistence of the collaborative and the single-user version of the application is based on this component because of its software properties. The first goal of this component is to render the current visited museum section on the PDA's display along with all the artworks contained in the section. In addition, this component manages the dialog between the user and the application, in particular, when an artwork is selected in order to obtain information about it. Currently, the rendering engine is based on two main components:

- *A database manager*, which manages a database containing all the data about the artworks such as their title or name, their date creation, their author, etc.
- *An XML parser*, the data about the museum organization are stored in a separate XML file which contains different kind of information such as the location of the section in the museum, the list of the items contained in the section (the list of artworks, the title of the next and previous sections) and their location in the section, the translation of any textual information in different languages (currently in Italian and in English), the file name of the images used to display the museum section maps and the icons, the file name of the several audio comments and videos. In output, the parser creates data structures that

represent the museum organization into memory. These data structures are manipulated by all the software components in both versions of the application. Details about the structure of the XML file are provided below.

In terms of design, the icons and the text displayed on the screen are considered as tagged objects identified by a unique id and stored in a list. In terms of interaction, when a user clicks on the screen, it is easy to find which object has been selected. In addition, this mechanism allows easy and dynamic adding and removing of objects from the screen. This feature is widely used in the collaborative part of the application, as described in the following section.

### **Properties of the rendering engine**

The design of such component, based on the XML technology, has interesting software properties that have been helpful for the development of both versions of the application but, also, for our future developments:

- *Flexibility (i)*: Firstly, from a developer point of view, the rendering engine is not dependent on the system and is not tied with its specificities such as the screen size and the number of available colours. Actually, this component is flexible enough to support a wide variety of devices. Currently, the application works for the iPaq technology and for desktop computers. Secondly, the actual design of this component enables us to develop an independent single-user version and helped us to develop the collaborative one. Indeed, in order to add collaborative and interactive objects in the interface, we do not have to access directly the rendering engine. We just have to manipulate the created data structures. Furthermore, all interactive

events generated by these new interaction objects are forwarded to the collaborative components without interfering with the single user part.

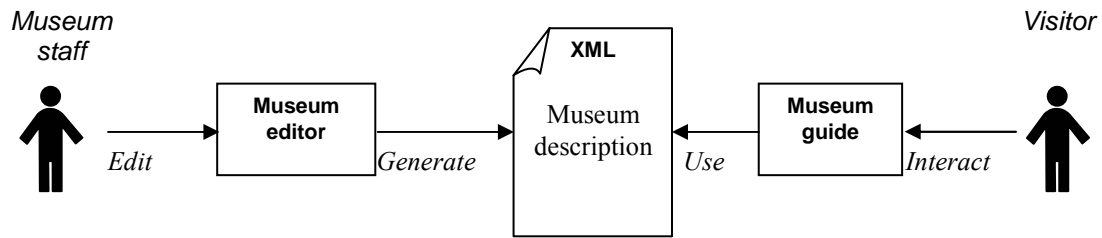


Figure 5. Museum update process.

- *Flexibility (ii)*: the museum is not a static place and the museum staff usually modify the organization of the museum, in particular, when a temporary exhibit is opened: some artworks are added, moved or simply removed. However, the members of the museum staff are not computer experts but our system must be flexible enough to reflect the real organization of the museum. For this reason, as shown in figure 5, we have developed a museum editor in order to modify easily the content of the sections, based on direct manipulation techniques. In output, it generates an XML file that is used by the Cicero system to render the graphic representation of each museum sections.

In addition, the rendering engine is not tied to the Marble Museum and the component can be used for any museum. Indeed, porting to another museum involves creating a new XML description with associated images (also stored separately from the application).

- *Internationalization*: through the XML description, we are able to support more efficiently language internationalization. In the current version, Italian and English are supported but it would be easy to support additional languages such as German. This mechanism is

widely used in many applications such as the Mozilla web browser (Mozilla project).

Our work is different from existing projects such as Made (Bellotti 2003b) which intends to manage the User Interface implemented by HTML pages through XML technology, or such as the Mozilla (Mozilla project) project which has developed high level mechanisms such as XUL (XML-based User Interface Language). In addition, we do not intend to provide another technology to describe the user interface but our goal is to manage interactive visits in museums. In our case, the XML technology, as detailed in this section, is used as means to manage the museum organization description and the interactions between the user, the artworks and the user's location in the museum.

### **Details of the museum organization 's XML description**

```
<museum>
  <map>
    <first>1</first>
    <sections>
      <section>
        <id>1</id><title>1</title><image>1</image>
        <orientation>LEFT</orientation>
        <coords>
          <X>471</X><Y>757</Y><W>156</W><H>233</H>
        </coords>
        <audio>StoriaTerr</audio>
        <items>
          <item>
            <id>10</id><type>artwork</type>
            <coords><X>10</X><Y>105</Y></coords>
            <parameters>
              <image>37</image><image2>74</image2>
              <resource>724</resource>
              <audio>1</audio><video>PiazzaAlberica</video>
            </parameters>
          </item>
          [...]
        </items>
      </section>
      [...]
    </sections>
  </map>
  [...]
```

</museum>

**Figure 6. Part of the XML file describing the Marble museum organization.**

All the data about the museum are stored in an XML file which is structured as follows. As shown in figure 6, the section descriptions are enclosed in the <sections> tag. Each section is identified by a unique id used, in particular, for automatic detection of the visitor location. A section is defined by a title, an image for the map. We also provide information about the orientation of the section: in the example shown in figure 1, the map has been rotated with an angle of 270° clockwise to represent exactly how the section is discovered by the visitor when he/she enters in a new section. The <coords> tags contain the coordinates of the section on the museum map. The <audio> tag indicates a file name for the audio comments about the section.



Each section contains a list of items (<items> tag) such as artworks enclosed in an <item> tag. In our example, the section contains an item that is identified as an artwork according to the value indicated by the <type> tag. Each item is also identified by a unique ID and the given coordinates indicate where the item is located in the section. Furthermore, additional data are available, in function of the item type, enclosed in the <parameters> tag. In case of an artwork, the item is represented by a database id and by two icons that show whether the artwork has been seen or not. The <audio> and <video> tags indicate if an audio comment and a video are available for this artwork.

Lastly, as shown in figure 6, each tag identifying a textual description or an image is represented by an integer value instead of a textual content or a file name. Indeed, the textual descriptions and the image file names are stored separately in the <languages> and <images> sections of the XML file. The

benefit is that the description of the museum sections is independent of any particular language and file name. With this approach, as explained above, it is easy to support a new language and any museum.

### 4.3 Collaboration management software layer

As highlighted in the previous paragraph, the rendering engine component is the main component of the single-user and the collaborative versions of our application. In particular, the dynamic aspects of the engine are widely used for the collaborative visit of the museum. Indeed, it is easy to modify, at any time, the content of the museum section and to add or remove the corresponding graphics items. This feature is used for:

- Visited artworks: when an artwork is seen by the visitor's companions, coloured bullets ●●, as shown in figure 1, appear on the screen.
- Shared enigma's Awareness icons: awareness icons (●● and  15 pts), as explained in section 3, are displayed to indicate how many clues have been found by the group and how the visit evolves. The value shown by these icons is updated automatically each time a member of the group solves a game. It reflects the state of the cooperation and its evolution.
- Educational games: the educational games are implemented as separated modules and are loaded at runtime as a dynamic library (the modules are in the DLL format under WindowsCE). When the application starts, the system parses a predefined directory where the games are stored and an associated object is created with its own data structures. The data used by these modules are also stored in an XML file which enables us to increase easily the number of educational games offered to the visitor during the visit. Furthermore, each game is associated to an artwork based on its id, the same used in the database and the XML description of the museum. Then, for each game, an icon is displayed , as shown in figure 1, next to the artwork icon. When a game is selected, the rendering engine sends the event directly to the corresponding module.

In terms of network, the communication between the PDAs is based on the multicast protocol and each PDA does not need to know the IP address of other devices. However, in order to initiate a collaborative museum visit, a

PDA must be chosen as a server to assign a unique ID to every visitor joining the current session: this ID is used for their identification by other users. Then, when the application starts, a peer-to-peer connection, based on the TCP protocol is established between the joining PDA and the dedicated server. Indeed, in order to avoid a heavy user interface, each visitor is identified by a unique colour, which corresponds to his/her ID. This metaphor is widely used in many "real" games such as trivial pursuit where players are identified by a coloured pie.

On top of the network manager component, as shown in figure 4, we have developed a concurrency control component responsible for the management of concurrent actions, in particular, when visitors are trying to solve the shared enigma.

## **5 User Evaluation**

A user evaluation has been conducted at the Marble Museum in Carrara involving ten users. We have evaluated how the cooperation between pairs of visitors occurs and how the gaming visit is perceived in terms of knowledge acquisition and enjoyment. The test involved four female and six male participants. The average age is about 29 years old. For this first user evaluation, we have considered groups of two persons for each session. In further experiments, we would consider larger groups. Before starting a session, users have received explanations about the manipulation of the user interface and about the meaning of the icons. At the end of the session, we have asked the players to fill a questionnaire. During the session, we have made observations and we were also available to help the participants when a problem occurred. The collaborative visit has been done in a subset of the museum and the duration of each session was about thirty minutes. The considered scenario was to find an artwork in the museum. In order to

identify the artwork, the participants had to win puzzle pieces, through the educational games, and to reconstruct the puzzle representing the artwork. In addition, our application has been instrumented in such a way to log the user actions. Such logs are useful to have precise information regarding the interactions actually performed and task performance.

### **Observations**

The first observations, extracted from the event logs generated by the user interactions with the system, show that users spent on average 12.2 seconds to solve the games. After selecting the game dialog, 46.6 % of participants chose to validate the answer; the remaining chose to go back to the main screen without answering in order to obtain additional information about the related artwork (53.4 %). In addition, 50.4 % of participants listened to a game-related audio comment about the artwork before looking at the question for the first time. Furthermore, they listened to the audio comment before validating their answer in 55.1 % of cases.

Secondly, as some participants informed us afterwards, getting the highest score is a strong motivation for cooperating with their companions and, as a consequence, makes them more interested in the content of the museum: "*I think the game makes the visitor more interested in the visit*" and "*trying to get the best score, we learn more*". We observed that in order to obtain the best score, some participants elaborated different strategies to validate an answer for each game. Indeed, each game allows only a "one shot" validation individually, but it gives a group of two participants two tries. Two kinds of strategies emerged: the first one is that one participant would give an answer and then tell the companion the result in order to try another if the first one was wrong; the second strategy is that both participants would discuss before providing the same answer.

We also asked the participants to give some comments about the usability of our system in order to improve it in the next version. We observed some problems or missing feature. For example, the system should provide more feedback about the educational games. In particular, it should indicate the answer provided by a companion. Furthermore, we may introduce some sound feedback into the interface in order to reinforce the group awareness such as playing a sound when the companion has solved a game. Another observed problem is the localisation of the companion. Some of the participants asked for a real-time location of the companion. Currently, we are able to provide a two-level location: at the artwork level (what is the last seen artwork) and the room level (in which room is currently located the companion). However, the current technologies do not provide real, economic and suitable solutions for that kind of application in the context of museum co-visiting.

### **Questionnaire**

At the end of each session, we asked the participants to fill a questionnaire. We asked them to answer ten questions in order to cover the following points: how the co-visiting is perceived in terms of enjoyability and learnability, how usable is the user-interface for its collaborative aspects, the usefulness of the shared enigma and how they were implicated in the collaborative activity. We also asked questions about the partner localisation: it seems to be an important aspect of museum co-visiting according to the comments provided by the participants. For each questions, we asked the participants to rate their answer on a scale from 1 (very bad) to 5 (very good). The percentages detailed below indicate the average rate of all the answers provided by the participants (the highest percentage is best).

Overall, they answered that they learnt many more things thanks to the games (87.5%) and found the interface easy to use (87.5 %) and understandable (81.2 %). Furthermore, the participants appreciated the collaborative approach of the gaming (87.5 %). However, it appears, as observed above, that the cooperation occurred more around the individual games and less regarding the shared puzzle (62.5 %). This is partly due to the lack of feedback from the interface level. Nevertheless, our approach is encouraging because the participants liked the idea of a shared puzzle (81.2 %) and understood how to use it easily (90.3 %).

In terms of feedback for partner localisation, we provide two possible levels: we are able to detect the room each visitor is in (using the infrared beamers) and the last artwork seen. Regarding the latter, we assume that a visitor should be somewhere near the last selected artwork. This is represented by coloured bullets which have been found to be useful for detecting which artworks have been seen by the partner and localisation (83.3 %). However, when the companions are in different rooms, the localisation task becomes more difficult (58.3 %). Some participants suggested providing real-time localisation of the gamers.

## **6 Conclusion and future work**

In this paper, we have presented a system that enables and supports co-visiting at the Marble museum of Carrara. Compared to the existing works, the novelty of our project is to promote communication and social interactions between visitors based on interactive and cooperative educational games embedded in mobile devices such as iPaq PDAs. Furthermore, with this system, we consider the individual museum experience and visitors can regulate the pace of their own visits more flexibly than in solutions as those proposed by the Sotto Voce project where

companion visitors share the audio comments. We have also presented the details of the software implementation of the system and, in particular, the rendering engine component which has interesting properties for supporting dynamic modification and adaptation to the characteristics of the device at hand. Based on this component, it has been possible to develop a generic application that can support any museum visit and co-visiting.

Future work will be dedicated to identifying further mechanisms to provide real-time feedback of the activities performed by other visitors.

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