The design of a handheld, location-aware guide for indoor environments

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Abstract. Because of the growing spread of mobile and small devices (like PDAs, mobile phones, etc.), designers and developers of interactive systems have to consider user mobility and the dynamic context of use. In this paper we discuss the design criteria we have defined for developing handheld location-aware systems for indoor environments. We analyse some of the technologies currently available for this purpose and examine how to use them in order to obtain location-dependent information. We report on our experience in designing a location-aware guide for museum visitors and identify possible design criteria for this type of system, which uses automatic detection of a change in environment to trigger the presentation of multi-modal, context-dependent information through a hand-held guide.

Keywords: location-aware guide, indoor intelligent ambient, design criteria, handheld interactive systems

1 Introduction

The growing spread of small but powerful devices opens up new scenarios in which users can interact with such devices in many environments in order to access the information they need at different times and locations. The context of use, which can change dynamically during usage, becomes very important during the design, and developers need to understand how to take it into account during their work.

Old paradigms in human-computer interaction, all addressed by traditional GUI mechanisms, need to be revisited [4] because of new elements such as the mobility of the users and the availability of interaction modalities unfettered by mouse and keyboards: voice, sound, gesture, and user position can also be used to interact with a system. Location-aware systems can be roughly grouped by the type of environment where they are used: indoor or outdoor. They differ not only in the features of the environment (noise, light, number of people …) but also in the technology exploited to detect user position: usually GPS for outdoor environments; various technologies for indoors. In this paper, we discuss the lessons learnt in designing a handheld location-aware system for indoor environments. This discussion is based on the experience related to developing an application that localizes user position by interacting with infrared emitters, and adapts the presentation of information to the current context of use. This solution can be easily applied in other context-

dependent indoor applications. We also provide users with audio feedback to help them interact with the application. We focused our attention on the museum domain because it is characterized by mobile users who need context-dependent information, which should be provided without disorienting them or interfering with their visit. This need was also highlighted by an empirical study of the first version of the Marble Museum PDA application, which did not include any automatic support for location detection [7]: several visitors complained that sometimes they encountered problems understanding where they were during the visit. The new, location-aware system is currently available to all the museum visitors of the Marble Museum of Carrara.
In this paper, after a discussion of related work, we analyse technologies to support location-awareness in indoor environments. Then, we introduce our case study and present a solution to identify user location, describing how we provide our users with information related to the current context by using the visual and audio channels. Lastly, we analyse the results of the evaluation test and summarise the lessons learnt from this work.

2 Related Work

To better support users in their daily activities, a system has to provide them with information they need while taking into account the context in which interactions are performed. This problem requires different solutions depending on where the users are, i.e., in an outdoor or indoor environment. Whereas in the former case, the GPS technology helps the developer to find an outdoor user's position, in the latter researchers have to find different solutions to localize users. In our work we focus on indoor environments. The museum domain has been considered by a number of researchers (see for example, [2], [6], [11]) because in such environments the users walk freely in a building, without a fixed path, and need information related to the context (i.e. section) they are. So, museums are an ideal test area for researchers in human-computer interaction with mobile devices. In the GUIDE project [6] visitors in outdoor environment supported through several WLANs are considered. In our work we focus on indoor visitors, this requires consideration of different environments and thus different solutions for supporting visitors.
In IrReal [5], the authors designed a building information and navigation system based on Palm Pilot PDAs and a set of powerful infrared emitters located throughout a building. When the users are walking in the building, the infrared sends them information related to their current position. The information is grouped in a cluster of "pages" connected to each other making an acyclic graph. These pages are broadcast using the infrared beacons. This solution has some problems, the first is that the information provided to the users concerns only nearby objects: this can be a problem in a large room because even if the users are near an object, they may be interested in a different object

whose description is contained in another group of pages (i.e., located far away). For each beacon, the pages are broadcast repeatedly: no back button is provided. Another problem concerns the cost of the solution: each beacon is connected to a PC in order to broadcast the pages.

In our solution we want to preserve the possibility for the user to move easily not only in the building, but also through the information in the system. We provide them with a back button that acts like the back button in Web browsers: so, for example, they can easily access the last artwork they visited.

Another approach has been proposed by the Cyberguide project [1]. In this project, the authors provide users with context-aware information about the projects performed at the GVU Center in Atlanta. They installed TV remote controllers throughout the building to detect users' locations and provide them with a map that shows the area neighbouring the user, highlighting corridors and nearby objects, such as project demos. In this way they have divided the building into a series of cells. The information on location (i.e. cell) and objects is provided in textual and graphical modalities. The users were also provided with the possibility of exploring the map of the entire Centre. The project authors intended to support the visitors' tasks by taking into account their positions and what they are currently looking at: to detect this information, they assume that the users are looking in the same direction they are walking. So, when the user passes from one cell to another, the system shows the map of the new cell where the user is entering, oriented according to this direction. This approach requires a large number of beacons and a consequently costly system. Moreover, the application provides the users with textual information. A better solution would be to use audio for the project presentations. In our solution, we use MP3 files to give users information about the artworks in the museum. This solution was appreciated by users who, as we will describe in the section about our last test evaluation, liked the possibility of observing the object of the presentation while hearing information about it. Also, in our solution we chose to install infrared emitters on the entrance of each section. In this way, installing only a small number of devices, we have implemented a low cost, easy to install system.

The two projects discussed so far address the problem of locating the user through interactions with infrareds in a generic building. Now let us examine a project that aims to detect user position specifically in a museum.

The Hippie system, developed in the HIPS project [11], locates users via an infrared system composed of beacons installed at the entrance of each section and emitters installed on the artworks. This solution creates a sort of infrared grid through which the system can detect the artworks nearest any given user. Hippie provides the users with the information related to the artwork nearest them, assuming that visitors stop walking only because they are near an artwork they find interesting. However, the design does not consider other potential reasons for stopping, such as a crowd preventing movement. This project also addresses the problem of how to adapt the user interface to the user model. The model can be modified either directly by the user at the beginning of the session or by the system, which takes into account the history of user interactions and the choices performed by the user; in both cases the system highlights proposals for further information to the user through a blinking light-bulb icon. The suggested information can be accessed through links to the descriptions of the works that best correspond to the current user model. When accepted, the suggestions are used to update the user model. The information is provided by taking into account the user model and the presentations are modified accordingly.

The limitation of this approach is that often the user position alone is not enough to indicate interest in the closest work of art. Thus, the risk is that the system erroneously identifies the user interests and determines the corresponding user model. Consequently, the audio presentations can probably be of little interest to the user. In our approach in order to prevent such wrong deductions that can negatively influence the visit, we have chosen to insure users' freedom of movement. Once the system has detected the room the user is in, then the user can freely activate audio comments regarding the artworks of interest.

3 Location Identification

The identification of a user's position in an in-door environment can be performed at various levels of granularity: for example, one is the identification of the exact user position, thus, in a museum application, the system can identify the closest work of art; another level is when the system is only able to identify the room where the user is located. We have discussed that the assumption that the time the user spends near a work of art is proportional to the interest in it may be incorrect because there are many reasons for a user to stop somewhere (it could be because of other visitors or some obstacles). This is one of the reasons for our choice of the second criterion. To explicitly localize the users in the museum, we have considered three technologies that allow mobile devices to offer some services: WLAN, Bluetooth and Infrared (IR). Table 1 summarises the comparison among these technologies and the next subsections explain the reasons for our choice.

3.1 WLAN

We studied the possibility of adopting the WLAN technology to localize the users during their visit. In our system we only need to know when users enter a new section. We would need to install an access point for each room and position all of them in such a way that the coverage areas of three access points overlap at the entrance of each section. Then, on the basis of the intensity of the signal received the server could identify the location of the user. An example of application of this approach has been developed for a hospital [10]. The system synchronizes the information in the user's PDA with the servers each time the device connects to an access point. For example, a doctor might leave on the server messages that describe recommendations for treatment to any nurse on the next shift or doctors can receive information about a patient when they arrive near the patient bed. In this project, the system detects the location of the users (doctors and nurses) by triangulating the signal strength from at least three 802.11 access points. Its reasoning component wraps a back-propagation neural network trained to map the signal strength from each access point in the wireless network to the user's location. There exist other algorithms used to localize users in indoor environment using WLAN technology [12]. The major drawback of these techniques is the calibration step that is necessary. Researchers have reported location triangulation within approximately 1-2 meters, but this often requires significant acquisition of sample signal data to achieve, making it difficult to realize in practice. In our case, the Museum covers a large area structured in many environments obtained through walls or panels made with various materials: the large data required by various algorithms and the structure of the Museum that complicates the identification of the access points location in such a way to minimize the ambiguity in the signal-strength caption, make very difficult the use of WLANs, as technology to locate users position. Another motivation is the cost of each access point because we would need a high number of them in order to obtain precise results in all the museum rooms.

3.2 Bluetooth

Bluetooth technology is characterised by the interaction between devices in a range of 10 meters. Once the discovery step is finished (between 5 and 10 seconds), Bluetooth systems can create a piconet (also called Private Area Network) composed of up to 8 devices that have open connections to each other. Once the piconet is established, the members randomly hop frequencies in unison so they keep connected. We wanted to develop a system that supports users during their visits in the museum. The interaction with the device has to be immediate because when the users enter in a new section, they should immediately receive the information regarding the section and the location of the artworks in order to prevent the disorientation of the tourists. Using Bluetooth technology, the visitors would have to stop at the entrance of each section waiting for the completion of the discovery step of their device. We thought that this discovery step is not suitable for museum visitors and that can be an obstacle for the full enjoyment of their visit. More generally, the Bluetooth technology seems more suitable to support wireless communication among a set of statically located devices rather than mobile visitors.

3.3 Infrared

Devices with infrared ports can easily communicate each other using protocols based on the IrDA standard. The IrDA protocols are characterized by an immediate communication and identification, if the devices are lined-up in a 30 degree angle and support a bit rate between 2400 bps and 4 Mbps. The shortcoming of this technology is that the devices should be lined up in order to start the communication. For example, in our system, to allow the communication between infrared beacons and the PDAs, at the entrance of a new section, the users have to take the devices in a vertical manner (as in a holding-and-looking-at-the-screen manner) because the infrared beacons are located on the ceiling. This usually does not create problems as they often hold the PDA and look to the screen keeping the device in such manner and receive a recommendation to keep it in this manner as soon as they interact with the guide.

	Area of interaction	Throughput	Time of Connection
WLAN	Range of 100 meters around the access point (in indoor environments without obstacles)	Theoretically 11Mbps but in practise closer to 4-5 Mbps	Immediately
Bluetooth	Range of 10 meters around another Bluetooth device.	Theoretically 1Mps but in practise closer to 700Kbps	Between 5 and 10 seconds to discover other Bluetooth devices
Infrareds	Sender and receiver should have the corresponding ports tilted at a 30-degree angle each other, point and shot style application	Currently, according to the protocol used by devices, up to 4 Mbps	Immediately after 2 devices are lined up.

Table 1: Comparison of wireless technologies.

As mentioned before, we intended to provide the visitors with the information regarding the section as soon as they enter. Having considered the pros and cons of these three technologies, we chose to adopt the last one because of the immediateness of the connection and the relatively low costs of the device and the installation. Each infrared beacon provides just an identifier of the new environment. This type of communication is sufficient because current PDAs can have one gigabyte of additional memory. This is sufficient to keep local copies of audios, images and videos on aspects to provide to users. In addition, other possibilities such as Internet access are not interesting for museum visitors whose main goal is to appreciate the artworks that are in the exhibition.

4 The case study

We have designed, developed and delivered an application for a museum, the Marble Museum located in Carrara [13], Italy. The managers of the museum decided to provide their visitors with information additional to that contained in traditional labels. While human guides are available for large groups, they can be too expensive for single visitors or small groups. In these cases an interactive guide can be a better solution to provide rich set of information that can be adapted to the visitors' interest. In our approach, the design is driven by three main elements: the context of use that includes both the device used for the interaction and the environment where such interaction occurs, the tasks users wish to perform and the objects they need to manipulate in their performance (both interface and domain objects).

4.1 Context of use

For the context of use, we consider the environment in which the interactive system should be used, the interaction platforms and the users of the interactive system who wish to achieve their goals through it.

In our case, the users can vary in terms of ability in interacting with computing devices and knowledge of the application domain. The structure of the museum forces to some extent the order of visit among the rooms. Some large rooms are somehow structured in different environments using some light panels. The rooms contain many types of objects from the ancient Romans to pieces of quarrying technology of the past century. Thus, visitors need support able to interactively select those more interesting for them and receiving related information. The application has been developed on Ipaq Compaq PDAs, with Windows CE and additional one Gbytes Flash Memory Card. The availability of new larger add-on memories, allows us to develop a stand-alone system that does not need to download multimedia files, avoiding the interferences with other devices and with physical object (such as wall, iron object etc.) typical of wireless data communication. We decided to use text-to-speech synthesis for supporting audio comments. In addition, the synthesized Italian voice was considered too unpleasant and was replaced with audio-recorded comments. The system was originally designed to provide audio information with headphones but the managers of the Museum noticed that visitors prefer to use the application sharing it in a small group (two or three visitors) without headphones, considering acceptable the mix of the audio presentation from different guide in the same section as this can happen rarely give the limited number of PDAs available. The mobile system reacts to user interactions with sounds, context-dependent information provided by text or audio channel to better support the users in their activity. Currently, the application contains description of about 150 works of art, each of them with an associated Jpeg picture (dimensions are about 140x140 pixels). The audio files are in MP3 format. The application requires about 4 Mbytes of memory. A new version of the application, functionally equivalent but with a more modular internal architecture is under development and will require about 400 Kbytes. The multimedia data (videos, images, vocal comments) require about 220 Mbytes.

4.2 Tasks

In the design of the user interface we considered three main types of tasks that users can perform in the context 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.
- *control the user interface*, for example, to allow change of audio comments' volume , to stop and start the comments, and to move through the various levels of detail of the museum information available;
- *access museum information*, also this is provided at different abstraction levels (museum, section, physical environment, single work).

4.3 Domain Concepts and User Interface

Through an analysis of the behaviour of museum visitors and the information provided by the human guides we identified three levels of information that are interesting for them:

- *Museum*, overall introduction and short information regarding its history and peculiar aspects;
- *Section*, information regarding the main features of the sections, the common aspects of the artworks in them and the motivations for their introductions. Most relevant artworks are highlighted as well.
- *Artworks*, the description of the artworks and additional information regarding them are provided.

If we follow a Web metaphor we can say that for each instance of a information level there is a page designed following specific criteria. In these pages there is information regarding not only the artworks but also supporting the orientation or the control of the navigation within the application.

The information is presented through a common structure that is filled in differently according to the level of information required. The main area is used to provide information regarding museum sections grouped by typology of artwork contained and supports change of language whereas the lower part provides a command bar with menus to control the application: close it, activate the audio output, go back to the previous presentation and so on. When a section is selected, the corresponding map is shown along with icons located according to the position of the corresponding artwork, and the entrance and exit are highlighted with arrows indicating the expected visit order. Through an icon selection, it is possible to access information related to the corresponding artwork. In this case the main area is used to show title and image of the artwork in order to better identify it and the lower area is used to close the presentation, activate a corresponding video, and go back. Figure 1 shows an example of presentation at the museum, section and artwork level.

Fig. 1. Example of PDA presentations.

5 Location-dependent Interaction

In order to determine user position, we have installed infrared emitters at the entrance of each room. We decided to use infrared beacons that send a unique identifier through the IrDA protocol for each room. The infrared beacons are located on the ceiling of the building so that the presence of other visitors does not interfere with the detection of a given user's access. When the user enters a new room the emitters send the identifier to the PDA, the application detects it and changes the presentation accordingly. The angle covered by the infrared beacons is 90° because each of them is actually composed of multiple emitters. This angle is sufficient to assure a good communication with the PDA assuming that the user keeps the device in vertical manner, even if it is not completely lined up with the infrared beacon. The infrared beacons have been purposely built for our application, even if their structure is simple.

The signal transmitted by the emitter is composed of eight characters. Initially we used only three characters; thus the string sent by the emitters had the following format '001@@@@@'. However, after the first experiments we realized that this solution needed to be improved because infrared waves can be reflected by surfaces. Consequently, the signal that reaches the infrared port of the PDA may be distorted. In this case, the signal may be misinterpreted because a three-character string with erroneous content is detected and the corresponding identifier would be different from that actually associated to the room the user is entering.

Indeed, when the first version of the application was tested, it happened often that the infrareds signals were distorted because of the rebounds, thus the string identifying the room was either completely corrupted or provided a wrong information (i.e. the identification of a room different for that of the room were the user was actually entering): to improve the recognition of the signal, a simple checksum of the character received would not be sufficient (because it is possible to have strings syntactically but not semantically correct). We decided to extend the string transmitted by the emitters by adding three characters that are used as "parity bits". Each number is associated with an alphabetical character: "0" is associated with "A", "1" is associated with "B", etc. The algorithm is simple: each time a new string is detected, the application checks that the part of the string composed of numerical characters corresponds to that composed of alphabetical characters. For example, a valid string is "001AAB@@". Thus, the application can correctly determine when it detects a correct signal indicating the room where the user has entered. The emitters have been developed adopting stand-alone technology: they are made in such a way as to transmit one eight-character signal per second. This solution was easy to install and with low cost.

5.1 Visual Feedback

When the users change the section they are visiting, they want information about the artworks they are looking at. So, the detection of the section where the users are is important to support them in their visit. In our system, this information is detected automatically through the interaction with infrared beacons: upon entering a new section, the application provides users with a Museum map, where the section is highlighted; after that, an audio presentation of the main characteristics of the section and a map indicating the location of the artworks in that section are provided to the users. In other words, we use location information only to provide the users with context-dependent information that helps to orient them in the museum. To avoid the problem caused by the failed misalignment between PDAs and infrared beacons, at the start of the visit session our system presents information introducing the infrared beacons in the museum and explaining how the visitors can solve problems related to failure of the system to detect their entrance in a new section. Moreover, displaying in each section map the physical elements available, such as walls and doors, our system reduces the effort for the users to orient themselves in the section.

Fig. 2. Visual feedback when entrance in a new room is detected.

The page related to the section that the visitors are leaving, goes on the top of the history queue accessible through the back button, together with all the pages the users visited. Through this mechanism visitors can revisit the already visited pages, for example, to compare artworks.

5.2 Audio feedback

The use of audio in the interaction between human and system plays an important role because the system can indicate its internal state: error, alert and information messages are generally displayed coupled with a sound associated to each event; in this case, the sound is used to call users’ attention to a system message. In our application, we decided to highlight the automatic detection of the room where users are entering, obtaining two results: the first it to signal this event to the users who might not be looking at the PDA display; the second reason is to assure the visitors that the system is aware that the context has changed and that the information is related to the new section. For example, in the Marble Museum there are sections, located in big rooms, which are logically but not physically divided in subsection. In this case, the system highlights the entering in new subsections acting as when users enter in new physical sections (i.e. playing the sound and showing the map of the new subsection). Doing so, we create a connection between sound and action that improve the orientation and the interaction of the visitors with the system.

The choice of the sound to use is important. To signal the event of entering new room, we have chosen the same sound generated when the PDA is connected to a desktop system. The rationale for the choice lies in the fact that an information link is established: when the application detects a new user position, to some extent it shows that there is a connection between the application and the surrounding environment, just as when the PDA and the application exchange information. As we discuss in the section on the user tests, the association of a sound to the section change helps them to get oriented in the museum. To improve the support to the users during the visits, we have also added audio feedback when the users select artworks on the section map to assure users that the system has received their input. We adopted this solution because we noticed that, after selecting an artwork, users often reselected the artworks because they were unaware that the system was processing the request. We want to avoid this kind of double-clicking because it can generate some confusion that can negatively influence the interaction of the users with the system.

6 Design Criteria for the Graphical Part

Designing an application for a PDA should take into account the specific features of this type of device: it provides a broader range of interaction techniques than current mobile phones. The possibilities are similar to those of desktop systems but there are two main differences: the limitation of the screen resolution and the possibility of using it on the go.

We have followed some criteria during the design of the application:

- **Web metaphor**, while not many users have had much experience with PDAs, most have some experience with Web browsers, which are characterised by pages that can be uploaded through links with the possibility of going back and forward through the page history. We have designed our application trying to implement similar features into our application, but also taking into account its specific goals. Thus, the resulting system is composed of a number of graphical presentations that can be navigated through icons. Each page is also associated with a voice comment automatically started the first time it is accessed. Using the back button in the toolbar it is possible to go back to the previous presentations in a way similar to that of Web browsers.

- **Navigation feedback**, in Web browsers, links that have been selected have a different colour from the others. This is a useful feedback for navigators. In our application we adopted the same design: icons associated with artworks already accessed have a different colour (red) from those associated with artworks yet to be visited (grey).
- **Orientation support in the surrounding environment**, in order to help users to orient themselves we provide various information: the map of the museum highlighting the section where the user is, and then a map of the section highlighting the physical elements that identify it (walls, doors, supports for disabled people). Each of these can be a sort of landmark useful for orientation. In addition, all the maps displayed by the system have the same orientation as that of users when entering in new sections.
- **Minimize graphical interaction,** in order to reduce the difficulties for the users to interact using both hands with the mobile devices while they are moving. For this purpose, in our system, as soon as the user enters a new section the application immediately starts a vocal comment to present the new section.
- **No redundancy in input commands**, in desktop graphical interfaces usually it is possible to interact through both lists of pull-down menus and icon toolbars. So, often the same command can be activated either through an element of a pull-down menu or through an icon. In our case, because the display has a very limited resolution, commands can be activated only through the icon toolbar.

7. Evaluation of the Application

In order to have feedback from real users a first test of the application has been performed. The evaluation involved visitors who were given a PDA with our application installed. After their visit to the Museum, they were asked to fill in an anonymous questionnaire. Thirty five museum visitors accepted to fill it in at the end of the visit. The goal of the test was to understand to what extent the application provides a valid support from various viewpoints: quantity and quality of the information provided, modality of presentation, interaction with infrared devices, capacity to orient themselves in the museum. In particular, the questionnaire was structured into various parts regarding:

- Previous experience in museum visits (4 questions);
- Quality of the information provided regarding the artworks in the museum (9 questions);
- Quality of the multimedia techniques used: audio, images, and videos (7 questions);
- Quality of the interactive part of the application: its use, the underlying concepts, the user interface (10 questions);

- Capability to support users’ orientation (10 questions);
- Some personal information, such as age, instruction, etc.

The test was composed of various types of questions: some of them required only positive or negative answers, others required a numerical scoring (on a scale from 1 to 7), and open questions aiming to stimulate critics and suggestions were introduced as well.
On average a visit took 73 minutes, 25 users were Italians, 18 were women, the average age was 37. 63% was graduated, 29% had a high-school diploma. Only 15 of them had already used a PDA before the experiment. In terms of age, no under 19 used it, however, the most numerous group was that with age in between 19 and 30 and the majority of the visitors was under 40 years old.

After collecting the data, we decided to analyse them using two criteria: the first, related to their nationality and the second related to users experience on PDA. The application provides audio information in either Italian or English obtained differently and we use the first criterion in analysing the data to verify if the different techniques for audio presentation (human voice for Italian visitors and text-to-speech engine for English) can lead to a different quality of the visit. The data show that foreign visitors appreciated the quality of the information more than Italians. In particular, the information regarding the museum sections received better ratings (average 5.72 with 1.10 standard deviation for Italian and 6.33 with standard deviation 0.71 for foreign visitors). The open questions provided indications of additional information content that users would appreciate, such as more information regarding quarrying in ancient time, including the quarrying methods used and the life of quarry men. The answers regarding the multimedia techniques show that the audio presentations were appreciated from both Italians and foreign visitors. Very high ratings were provided to the videos whose utility was highlighted by most visitors. Some problems were raised for the images. Some visitors were dubious regarding their dimensions and clearness.

We individuated two categories, expert (who already had a similar experience) and novice (who used a PDA for the first time), and used the second criterion (related to the users experience in the use of PDA) to verify the impact of our design criteria on the visitors: the questions regarding the interactions with the electronic guide aimed to understand its actual utility and evaluate its usability leaving to the visitors the possibility of suggesting further improvements. Analysing the utility of the electronic guide, we noticed that novices and experts provided similar ratings (on average novices assigned 6.47 with 0.62 standard deviation whereas experts provided 6.40 with 0.74 standard deviation). Regarding the easiness of use, the experts provided best rates (average rating

6.60 with 0.63 standard deviation) while novices asked for improvements (average 6.28 with 1.23 standard deviation). Similar ratings were provided for the user interface, experts users found the interface rich of possibilities and clear to use, while novice users provided similar ratings with higher standard deviation and suggestions such as “the possibility of adding arrows to go forward and backward” or “improve the correspondence between the real objects in the room and the icons in the application”, thus showing that some problems can arise when users interacting with the application have no previous experience with PDAs.

Regarding the interaction with the infrareds, the questions addressed issues such as their utility to support orientation, the ease with which users interact with them and localize the section where they are. The data gathered show that also in this case there are differences between experts and novice users. The former provided high ratings in a consistent manner, while the ratings provided by the novice users show that they found some difficulties in orienting themselves and identifying the current section. However, despite such difficulties they did not provide any particular suggestions. Some visitors provided comments regarding the location of the artworks in the rooms. One said “it would be useful to have maps that change the orientation according to the user movements”.

From the analysis of the data it is possible to understand that the most appreciated part of the application is the quality of the information, for example foreign visitors particularly appreciated the videos showing dynamic information related to the artworks in the museum. Novice users had some problems, both in the interaction and in the orientation but in this case it seems that the lack of familiarity with palmtop systems was a major cause and the use of infrareds added a further level of difficulty.

8 Improving User Experience

In order to improve the user experience new features have been designed and implemented. As highlighted by the test evaluation of the system, visitors asked for improvements that could help them during the visit. We have provided the users with oriented maps and a “path finder” feature, which finds the location of an artwork they are interested in.

The system defines the user position in terms of the section or subsection where the user currently is. It provides the user with the section map oriented according to the point of entry into the section. We adopted this solution because we wanted the users to orient themselves as soon as possible. The next figure shows an example of a map oriented according to the user’s point of view.

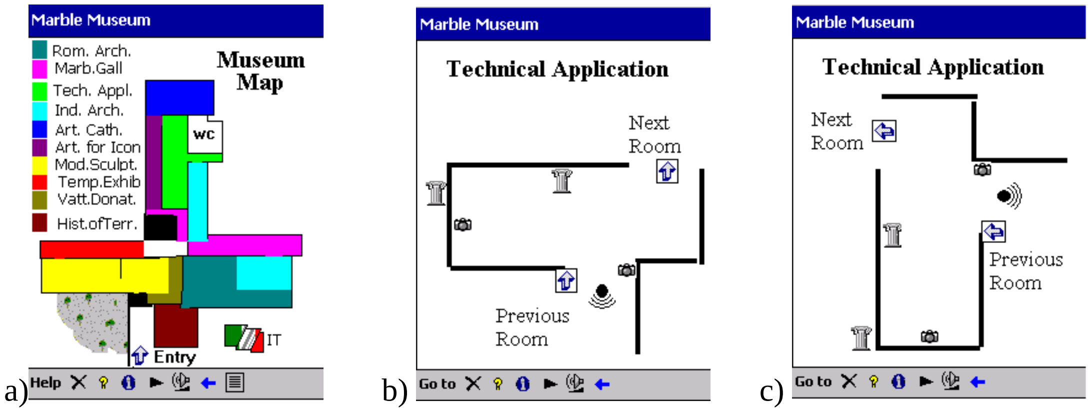

Fig. 3. Example of Section Map.

Figure 3 displays: a) the Museum Map; b) the section map in the Museum Map (this section is coloured in green) oriented to the entrance; c) the section map displayed from a different perspective.

The Path Finder method implemented allows visitors to find the location of an artwork they are interested in by suggesting the path to reach it starting from the room they are in. The result of the request is a map highlighting the section where the user currently is, the section where the artwork is located and the path that the user is to follow to find the artwork. The next figure shows an example of the result of a user invoking this feature and interacting with the system.

Fig. 4. Examples of Path Finder activation.

The output of the Path Finder is a museum map, oriented to the new section's entrance. The highlighted path is location-aware: when the user starts to follow the path, each change of section is tracked and the museum map will change according to the new context and the current section is highlighted (see Fig.4).

Conclusions

After analysing benefits and drawbacks of various technologies we have discussed our experience in developing a museum application in this field. We report on the results of the evaluation of such application. We have also identified a number of design criteria that can be adopted for other applications that share similar requirements.

Future work will be dedicated to the possibility of providing location-dependent support that takes into account also the preferences of the current user and perform a new evaluation study through an evaluation tool based on the intelligent analysis of the logs of the user interactions and electronic questionnaires. In addition, we also plan to support visitors through a variety of interactive devices (such as large screens) so that the PDA can be used in combination with them and to consider RFID technology to provide additional location-related information.

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