Design Criteria for Location-aware, Indoor, PDA Applications

Carmine Ciavarella, Fabio Paternò

ISTI-CNR
Via G.Moruzzi 1
Pisa, Italy
{c.ciavarella, f.paterno}@isti.cnr.it

Abstract. The design of interactive systems has to take into account the context of use. In this paper we discuss the design criteria to use when developing location-aware, indoor, PDA applications. We analyse some of the technologies currently available for this purpose and examine how to provide users with location-dependent information. The discussion of such criteria is based on our experience in the development of an interactive guide for museum visitors.

1 Introduction

Nowadays mobile devices have powerful computing capabilities. This opens up new scenarios where users can interact with them in many environments, so that they can access the information they need anytime, anywhere. 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. In this paper we want to discuss the criteria for designing location-aware, indoor, PDA applications. This discussion is based on an experience in developing an application that localizes users' positions by interacting with infrared emitters, and adapts the presentation of information to the context of use. This solution can be applied in other context-dependent indoor applications, where the user's position cannot be tracked through GPS. Another advantage is that it provides better results than using wireless LANs [6] or Bluetooth technology for identifying the users' location in indoor environments. We also provide users with audio feedback to help them in interacting with the application.
The museum domain has been considered by a number of researchers (see for example, [2], [6], [10]), and is characterized by mobile users who need context-dependent information, which should be provided without disorienting the user. 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.

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 audio feedback. After that we analyse the results of the evaluation test and we 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 outdoor users' positions, in the latter the researchers have to find different solutions to localize user positions. In our work we focus on indoor environments. The museum domain has been considered by a number of researchers 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 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 with 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 Center. 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 two projects that aim to detect users position specifically in a museum.

The Hippie system developed in the HIPS project [10], 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 presentations are modified accordingly.

The limitation of this approach is that often the user's 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 will 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.

Another work has been proposed [2] for visiting "Filoli", a Georgian Revival house. In this case the application provides the users with an image of the current room with the works of interest highlighted by red borders. Then, the user can select the object of interest with a pen, which activates an audio comment or a video. It is possible to change the viewpoint of the room's representation by selecting one of the device's buttons; when the users want to enter in a new room, they have to indicate explicitly to the system by selecting the door of the next room in the last photo. In this project, one possible limitation is the use of pictures to represent the room content duplicating the information that the user is already seeing, with the risk of requiring multiple interactions to identify the selectable elements of interest. In addition, this solution is valid only for those museums where the elements of interest are arranged along each wall, while it becomes difficult to follow in cases where they are spread throughout the room. Our system detects automatically the room where the users are and provides them with a sound each time they enter in a new section. This audio feedback assures the users that the system is aware of the change of the context.

3 Support for 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. The first case can be useful to try to identify what works of art are more interesting to the user based on the assumption that the time the user spends near a work of art is proportional to the interest in it [10]. However, this hypothesis may be incorrect because there are many reasons for a user to stop somewhere (it could be because of other visitors or some obstacles). Thus, erroneous deductions may negatively influence the application in determining user interests. 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 recent technologies that allow mobile devices to offer some services: WLAN, Bluetooth and Infrared (IR). In the next subsections we analyse advantages and disadvantages of each of them and explain the reasons for our choice.

3.1 WLAN

WLAN technology allows devices to immediately connect to Internet/Intranet in a range of 100 meters (in indoor environments without obstacles) without any cables using an access point and a PCMCIA wireless Card. As in a classic LAN, a group of devices with wireless cards installed creates a wireless Intranet and can theoretically share files at 11Mbps (but real throughput is closer to 4-5Mbps [8]). The connection via WLAN has a high cost in terms of battery power of the devices and this can be a problem for mobile users. It also requires an external PCMCIA card to connect to the network until this technology is available directly on the motherboard of the devices. Moreover, walls and iron objects can interfere with the signal. To locate the position of the users in a building, WLAN is not so simple a solution because the system has to apply triangulation methods [3] to the data coming from the three access points nearest the user. Thus, the developers have to devote a great deal of attention when installing access points to prevent ambiguous situations on the borders of the intersections of the covered areas.

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 the 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 at the entrance of each section three access points overlap their coverage area. Then, on the basis of the intensity of the signal received the server could identify the location of the user. The problem was that we have not been able to find a solution that univocally indicates what section the users are entering because of the issue of the overlapping area, which was in some cases larger than some sections of the Museum. Another motivation was the cost of each access point: we would need 19 of them and consequently the cost of the system would increase.

3.2 Bluetooth

This recent technology has been introduced to avoid the problems we hinted at before. Bluetooth is a de facto standard for very low powered connections. Nowadays, Bluetooth is commercially available for many devices. The interaction between Bluetooth devices starts from a distance of 10 meters. The devices are grouped in *piconet* (i.e. 8 devices). Bluetooth allows users to connect easily to devices such as printer or headphones or to Internet via hot spots [8]. Once the connection is established, two ore more devices maintain the connection in spite of interference of walls or iron objects. The Bluetooth devices can share files at theoretically 1Mbps. Bluetooth communication protocol is composed of a preliminary step called "discovery": during this step the devices have to discover if there are other devices to interact with. This step costs in terms of time (between 5 and 10 seconds) [11] that each user has to wait before starting the communication. Once the discovery step finishes, the communication remains open until one of the two devices goes outside the range of the other. 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, we want to offer them, immediately, the presentation of the section and the dislocation of the artworks. In this way we prevent the disorientation of the tourists. Using Bluetooth technology, the visitors would have to stop their moving at the entrance of each section, waiting the discovery step of their device. Also, if the museum is crowded, there is the possibility that more than 10 people can visit the same section: there can be problems in finding the piconet to enter in. We thought that this discovery step is not so natural for museum visitors and that can be an obstacle to the full enjoyment of their visit.

3.3 Infrared

IrDA protocol of communication supports high data rates (4Mbps), point-and-shoot style application. It is also characterized by non-interference with other electronics devices. The technology involved is the same of TV remote controller: the cost is not so high like WLAN and Bluetooth solutions. IrDA signals rebound over the surfaces: the developer has to take into account this peculiarity. The communication over IrDA protocol involves only another device at time and requires that sender and receiver are aligned or the interaction occurs within a 30 degree cone angle (which means that sender and receiver should have the corresponding ports tilted at a 30-degree angle each other).

As mentioned before, we intended to provide the visitors with the information regarding the section they are entering, at the instant 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 manufacture and the installation. In addition, we noticed that we did not need to support communication of data during the user visit because current PDAs can have one gigabyte of additional memory. This information is sufficient to provide users with audios, images and videos on related aspects. In addition, during a museum visit a user is not interested in navigating in the Web because their main goal is to appreciate the artworks that are in exhibition.

4 The case study

We have developed and delivered an application for a museum. The application has been developed for the Marble Museum. The managers of the museum decided to provide their visitors with information additional to that contained in traditional labels. While guides are available for large groups, they can be too expensive for single visitors or small groups, an interactive automatic guide is a better solution in these cases. 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 considered for the interactive system, 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. Such 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 a Compaq Ipaq 3660, with windows CE and additional one Gbytes Flash Memory Card. We decided to use text-to-speech synthesis for supporting audio comments. Unfortunately, the possibility of dynamic text-to-speech generation is not supported in these environments because the necessary libraries are lacking for Windows CE. In addition, the synthesized Italian voice was considered too unpleasant and was replaced with audio-recorded comments.

The mobile system reacts with sounds, context-aware information provided by text or audio channel to better support the users in their activity. The system interacts with users reacting to their change of the section providing them with audio feedback.

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. For the English version we have used text-to-speech provided by Text Aloud MP3. The application requires about 3 Mbytes of memory, with about 220 Mbytes of multimedia data (videos, images, vocal comments).

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. 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.
- *control of the user interface*, for example, to allow changing 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).

4.3 Domain Concepts and User Interface

Through an analysis of the behaviour of museum visitors and the information provided them 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 level of information there is a page designed following some criteria. In these pages there is not only information regarding the artworks but also supporting the orientation or the control of the navigation within the application.

Figure 1 shows how a generic presentation is structured. The main area is used to provide information regarding the artworks whereas the lower part provides a command bar with menus to control the various parameters of the application.

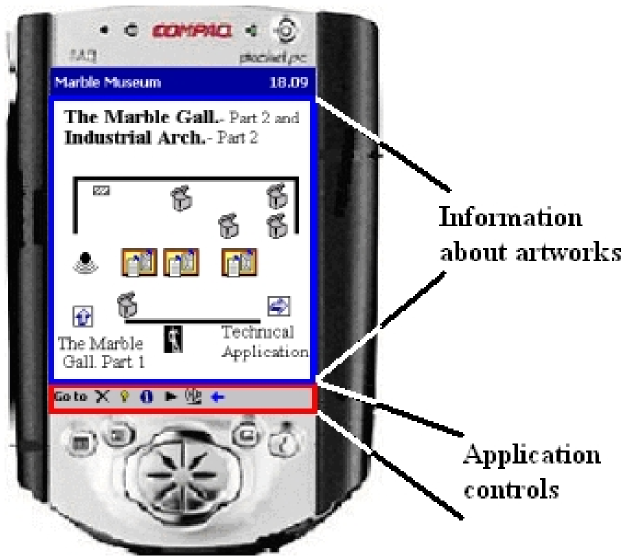

Fig. 1. Structure of a generic presentation.

5 Location-dependent Interaction

In order to determine user position, we have installed infrared emitters at the entrance into each room (see Figure 2). Such emitters have been expressly made for our application. They transmit a unique identifier through the IrDA protocol. 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 emitter is 90°. 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 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 not respect the spectrum of the IrDA protocol, then it can be misinterpreted. In this case, we can obtain three character strings with erroneous content because the identifier detected is different from that associated to the room where the user is entering.

Fig. 2. Example of interaction between a visitor and an IR emitter.

Indeed, when the first version of the application was tested, it happened often that the infrareds signals distorted because of the rebounds, thus the string identifying the room was either completely corrupted or provided a wrong information (the identification of a room different for that of the room were the user was actually entering). Thus, we have extended 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 data 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 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 furnish the users with context-dependent information that help them to orient themselves in the museum.

Fig. 3. Visual feedback when entrance in a new room is detected.

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. The choice of the sound to use is important. In this case 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 show in the section on the user tests, the association of a sound to the section change help 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 act as a sort of landmark that can be useful for orientation. In addition, the map is displayed with the same orientation that the user has when entering.
- **Minimise graphical interaction,** for this purpose as soon as the user enters a new section or selects an artwork then the application immediately starts a vocal comment.
- **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. A group of users (35) received a PDA with our application installed at the entrance of the museum. 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. At the end they had to fill in a questionnaire with many questions 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.

The application provides audio information in either Italian or English. 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).

From the open questions, we found the need for more information regarding quarrying in ancient time, for example the quarrying methods 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.

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. To analyse the answers received, it can be useful to distinguish between novice users (who used a PDA for the first time) and expert users who already had a similar experience. Analysing the utility of the electronic guide, we noticed that novice and expert provided similar rate (novices provided 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.

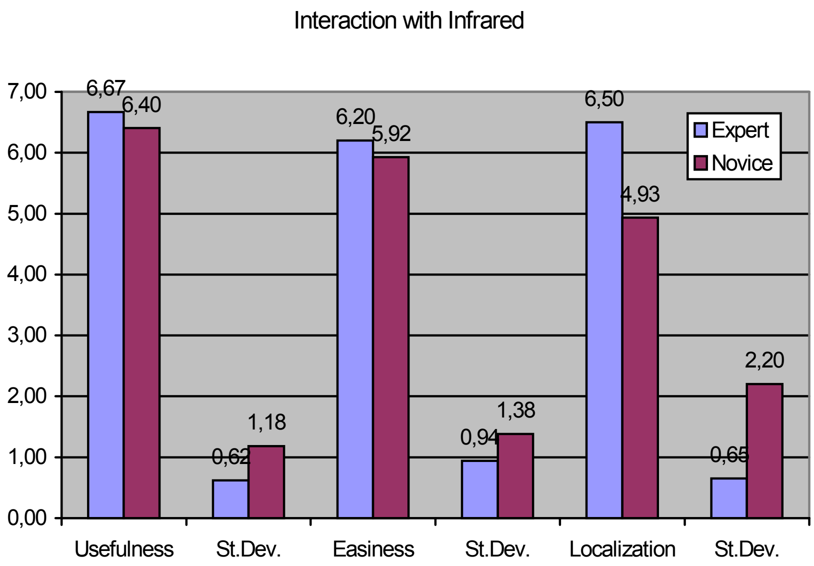

Fig. 4. User feedback on interaction with infrareds.

The bar chart in Figure 4 shows 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 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.

Conclusions

We have discussed criteria for designing location-aware, indoor applications. After analysing benefits and drawbacks of various technologies we have discussed our experience in developing a museum application in this field. We also report first results of the evaluation of such application and we identify 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 apply an evaluation tool based on the intelligent analysis of the logs of the user interactions.

References

1. Abowd,G.D., Atkeson,C.G., Hong, J., Long, S., Kooper, R., Pinkerton, M.: Cyberguide: A Mobile Context-Aware Tour Guide. Baltzer/ACM Wireless Networks, Vol. 3. 1997.
2. Aoki, P.M., Woodruff , A.: Improving Electronic Guidebook Interfaces Using a Task-Oriented Design Approach. Designing Interactive Systems, 2000, pp.319-325, ACM Press.
3. Bahland P. and Padmanabhan, V.N.: RADAR: An InBuilding RF-Based User Location and Tracking System, Proc. IEEE Infocom 2000, IEEE Press, Piscataway, N.J., 2000, pp. 775-784.
4. Bellotti, V., Back, M., Edwards, K., Grinter, R.E., Henderson, A., Lopes, C.: Making Sense of Sensing Systems: Five Questions for Designers and Researchers. Proceedings of CHI 2002, Minneapolis, USA, 2002, pp. 415-422, ACM Press.
5. Butz, A., Baus, J., Kruger, A.: Augmenting buildings with infrared information. In Proceedings of the International Symposium on Augmented Reality ISAR 2000, 2000, IEEE Computer Society Press.
6. Cheverst, K., Davies, N., Mitchell, K., Friday, A., Efstratiou, C.: Developing a Context - aware Electronic Tourist Guide: Some Issues and Experiences. Proceedings of CHI 2000, The Hague, Netherlands, 2000, pp 17-24, ACM Press.
7. Ciavarella, C., Paternò, F.: Design of Handheld Interactive Support, Proceedings DSV-IS 2002, Rostock, Germany.
8. Davies, A.C.: "An overview of Bluetooth Wireless TechnologyTM and some competing LAN Standards", Invited Plenary Lecture, Proc. of 1st IEEE International Conference on Circuits and Systems for Communications, St Petersberg, Russia, 26-28 June 2002. pp 206-211.
9. Mori G., Paterno` F., Santoro C. : Tool Support for Designing Nomadic Applications. Proceedings ACM IUI'03, pp.141-148, January 2003, Miami, USA.
10. Oppermann, R., Specht, M.: A Context-Sensitive Nomadic Exhibition Guide. In the Proceedings of Symposium on Handheld and Ubiquitous Computing, pp. 127 -142, LNCS 1927, 2000, Springer Verlag.
11. Woodings, R., Joos, D., Clifton, T., Knutson, C.D.: "Rapid Heterogeneous Ad Hoc Connection Establishment: Accelerating Bluetooth Inquiry Using IrDA." Proceedings of the Third Annual IEEE Wireless Communications and Networking Conference (WCNC '02), Orlando, Florida, March 18-21,2002.