

Design of Handheld Interactive Support

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Abstract. The growing availability of small devices whose computational and interactive resources are continuously increasing in terms of power and capacity has raised an interesting discussion on how to exploit them to support users in various contexts of use. We propose a solution that can be easily adopted for users such as museum visitors. The basic elements are the use of a multimedia PDA (without the use of location-aware technology) whose main purpose is to support a user who can move freely about within a museum. The structure of the user interface allows users to easily orient themselves through appropriate visual representations and then sees to providing the information that can be interesting for them by exploiting the multimedia capabilities of the device. In this paper we describe and discuss our initial design in a concrete case study, the related user feedback received from many visitors, and the design improvements obtained by considering users' experiences.

1 Introduction

The growing availability of small devices whose computational and interactive resources are continuously increasing in terms of power and capacity has raised interesting issues on how to exploit them to support users in various context of use. In this work we consider users who freely move about a building (in particular, in a museum). In such environments the most effective support is currently provided through either interactive multimedia kiosks or interactive audio recorders. In the former case, the main limitation is that the kiosk does not allow the user to move while receiving information, whereas the latter allow the user only to hear predefined texts associated with each work.

In the meantime, especially at research level, an increasing interest in location-aware systems has arisen with the goal of better assisting users. However, systems based on automatic generation of location-aware information suffer from the limitations of adaptive systems, in which often users interact with an interface that changes in the attempt to better support them, but which in doing so actually either makes wrong inferences or causes disorientation. For example, one typical problem with location-aware, in-door systems is that they can automatically generate information regarding the closest work of art while the user is actually looking at one that is located farther away. In addition, location-aware systems often require

technology that is either expensive or difficult to install in a widespread manner or do not work perfectly in all circumstances. For example, infrareds need to be installed for each work of art and require that the emitters and the receivers are lined-up in order to communicate. This can be difficult to afford, for examples in museums with hundreds of works of art and limited budget, such as the one considered in this study.

In our work we have designed an application that aims to overcome such limitations. We propose a solution that can be easily adopted without requiring expensive, sophisticated or difficult-to-install technology. The basic elements are the use of a multimedia PDA (without the support of location-aware technology) whose main purpose is to support a user who can move freely about within a museum. The user interface is structured in such a way as to allow users to easily orient themselves and then provides the information that can be interesting for them. Our evaluation involved 95 users, whose opinions and suggestions led to the final version of the application. This version is, at the present, in use and available for all the museum visitors. In this paper we discuss and report on our initial design, the user feedback, and the improved design. Some features of the two designs are also described using the ConcurTaskTrees notation in order to provide precise descriptions of how tasks are supported and their possible dynamic behaviour.

2 Related Works

The growing availability of small devices whose computational and interactive resources are continuously increasing in terms of power and capacity has raised interesting issues at research level on how to design usable interfaces for applications exploiting such devices. For example, in [9] some techniques are proposed to support multiple users communicating through heterogeneous devices. The concept of plasticity [3] has been introduced to indicate user interfaces able to support adaptation to different interaction platforms.

Some project addressed similar issues. The aim of GUIDE [11] is to investigate the provision of context-sensitive mobile multimedia support for city visitors. It is based on wireless network, located in Lancaster: information about positioning are transmitted from strategically positioned base station. This system use out-doors technologies that cannot be proposed for in-doors environments like museums. Museums are an interesting application domain for interactive mobile devices. Museum visitors can be assisted in various manners. One possibility is the use of Audio Tours: visitors can use a sort of large telephone receiver; see for example [1]. They can select the work of interest by entering its code through a numeric keypad. Audio Tours are precursors of electronic guides. They are useful but have a very limited visual channel.

This problem can be solved by using devices, like PDAs, that support both audio description and images. Another problem remain unsolved: user orientation inside the museum. An approach is suggested by IrReal project [12]: they build a navigation system using infrared transmitters. These transmitters, placed at strategically important points throughout a building, are useful to provide for way directions or other

localized dynamic information. This approach, is not completely suitable for museums where visitors have specific requirements.

A more interactive support has been adopted in the *Whitney Museum of American Art* in New York. The application is implemented on a tablet PC and integrates the description of the works of art with videos and interviews. The basic idea [6] is that visitors can download information from the museum web site [10] during the visit through a wireless network. The problem is that the time it takes to find and download interesting information is often long and the tablet is difficult to manage by mobile visitors, as it is rather cumbersome.

In location-aware systems the information regarding works or sections is selected depending on user position and length of stay in that position. This information is used to understand what the user's interests are. This approach has been used for the Hippié system [4] within the HIPS [5] project. The authors have also considered how to effectively present information to the user while taking into account the user model (interests and preferences of users). 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's taking 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. 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 limitation of this approach is that often the user's position alone is not enough to indicate interest in the closest work of art; external reasons, such as a crowd preventing movements, can be the reason for a user's stopping. Thus, the risk is that the system wrongly identifies the user interests and determines the corresponding user model.

One solution to the limitations of location-aware systems 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. In this case, 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.

In the next section we will discuss our solution that, while agreeing with the approach proposed in the aforementioned work on the limitations of location-aware systems, proposes a different way to represent and select information of interest.

3 Initial Design

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).

3.1 Context of use

For the context of use, we consider both the interaction resources used and the environment where the user performs the tasks.

The application has been developed on a Compaq Ipaq 3660, with windows CE and additional 64 Mbytes 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.

Currently, the application contains description of about 130 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. Overall the application requires about 30 Mega of memory.

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. They often had the problem to find guides able to provide such information and in some cases the guides were not able to communicate with foreign people. 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.

3.2 Tasks

In the design of the user interface we considered three 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).



Figure 1: Presentation of orientation information

At any time the application was 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 was triggered by selecting the “i” button on the bottom menu-bar that appears when the map of a physical environment is displayed (for example, see Figure 3).

In order to represent the task model underlying our design we have used the CTT (ConcurTaskTrees) notation [7]. It also allows us to provide precise descriptions of how tasks are supported and their possible dynamic behaviour.

Figure 2 shows an excerpt of the task model associated with the initial design of the application developed, in particular, it represents the initial part of a user session.

In the first version, the application’s opening presentation contained basic information regarding the museum, then, after user selection (*StartVisit* task), the application identified the current level of information to provide (*CalculateApplLev* task) and showed the museum map and provided audio comments regarding the museum and its history. In the map users could select the section (*SelectSection* task) where they were in order to obtain the related section map with indications of the positions of artworks while receiving audio comments on the section. It was also possible to display information regarding the location of the current room in the map and explanation of the icons and controls available in the user interface. The part of

the task model related to the visit of the selected section is not expanded for sake of brevity.

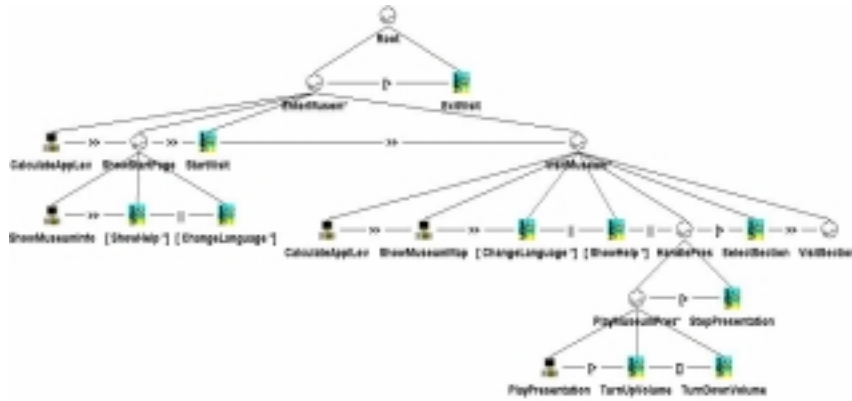


Figure 2: Part of the task model associated with the initial design

3.3 Objects


The information regarding the museum and the works that it contains is provided using both the audio and the visual channel. The visual information is mainly used to allow users to orient themselves and receive some supplementary information. It provides information at different logical levels:

- The museum, it displays a map that shows the logical organization and the physical structure of the museum.
- Sections, the map of each thematic section of the museum is provided, when it covers multiple physical environments it is possible to select each of them to get more detailed related information,
- Environments, they are either rooms or separate environments partitioned with various techniques; the system provides a map with icons indicating where the main objects of interest are located;
- Works of art, in this case a picture and basic information are provided.

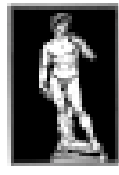
Since the museum considered is an interdisciplinary museum that contains various types of works, different icons are used to represent each type:

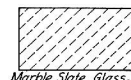



for showcases containing historical artefacts, models or reproductions;

 for pictures or photos hung on the museum walls.

 for capitals.

 for representing sculptures.


*Marble, Slate, Glass,
Porcelain, Etc.* for the marble exposition.

 for the reading-desks.

An alternative solution would have been to use pictures of the works considered in the room map instead of icons. However, the resolution of the PDA (240x320) would have made it difficult to interpret such images. The picture below shows an example of room map annotated with icons highlighting the main works of interest. The doors represented in the map are interactive and allow the user to change the room representation in the PDA (while physically moving in the new room).



Figure 3 Room map annotated with icons.

4 Presentation of information and navigation

The audio part has been implemented reflecting the logical structure of the information to provide. There are comments introducing the museum, its sections, each environment and each work located in them. They are provided in two languages: English, using text-to-speech synthesis. The resulting audio message is a bit metallic, but clearly understandable even by non-native English speakers. The other language is Italian, for which a pre-recorded female voice was used for the comments because the synthesised speech was considered unpleasant.

The resulting navigation was based on the museum map. The user started the visit from the museum map. Then, they selected the section of interest. Lastly, in the section map they could select the physical environment of interest and at any time they could go to the museum map to select another area. Figure 4 shows an example of sequence of accesses.



Figure 4 Levels of navigation in the first version of the guide.

5 Evaluation

This evaluation aimed to establish whether our *electronic guide* satisfied museum visitors' demands. We were particularly interested in determining:

- If our user interface allowed visitors to use the application properly;
- The quality and quantity of information provided about the museum art;
- How well our system helped visitors to orient themselves in the museum.

The test took place in the Marble Museum of Carrara during the summer, when the number of visitors is highest. The evaluation involved tourists who were given a PDA on which our application was installed. After their visit to the Museum, they were asked to answer some written questions about:

- Their previous experiences visiting museums (7 questions).
- Quality of information given (15).
- Quality of images and audio presentation offered (4).
- The electronic guide used during the visit (20).
- Some personal information.

The questionnaire was composed of items asking for a rating on a scale from 0 to 10 and open questions asking users to provide comments or suggestions on each aspect of the electronic guide. In the following we discuss the results of the questionnaire.

5.1 The users

The test involved 95 users; 34 of whom were Italian. The following charts show some data about users.

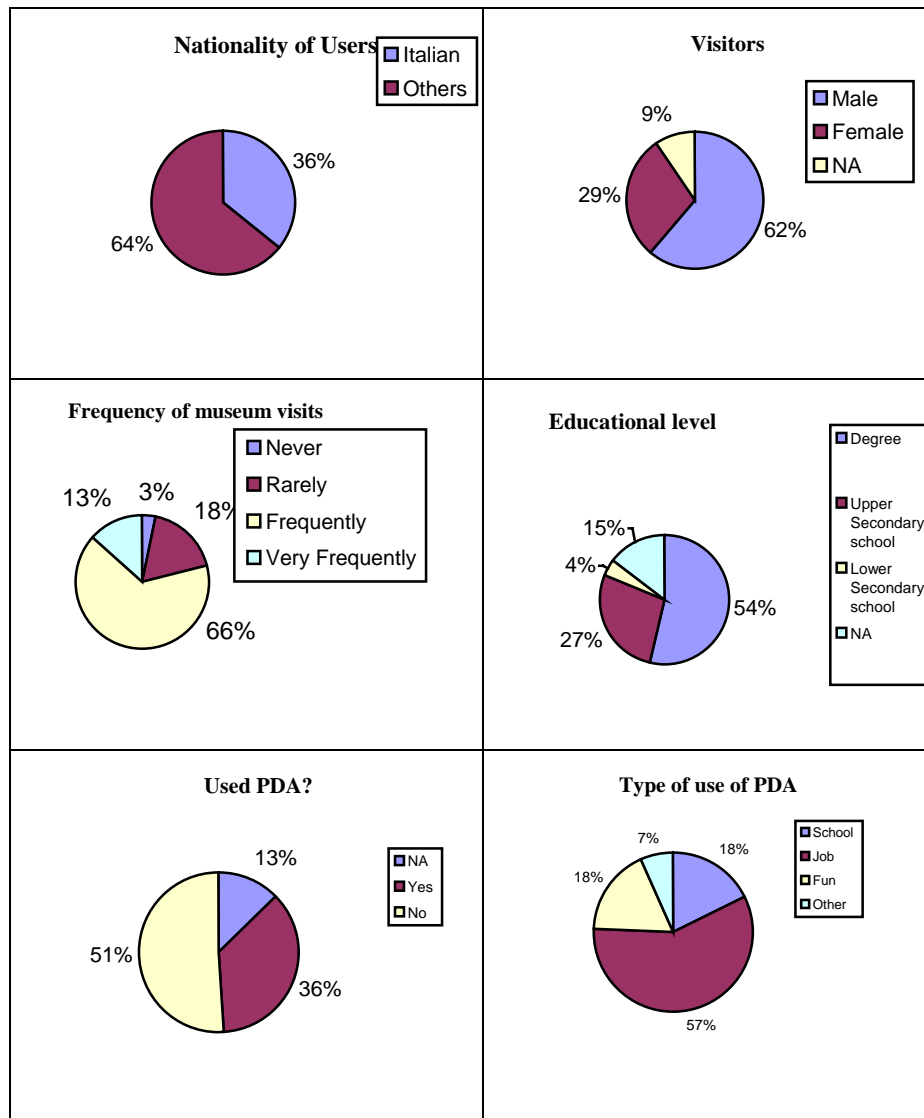


Figure 5: PieCharts representing users' characteristics.

The foregoing charts reveal that most visitors were male (62%). The average age was 35. Most visitors (28%) were aged between 31 and 40 and had a university degree

(54%). Moreover, a large majority (66%) visits museums frequently: 28% of these in fact had had at least one experience with electronic museum guides. An interesting fact was that only 36% of visitors had previously used a PDA, and most of them (54%) only for work. These data highlight that our system was quite novel, in both its aspects: the concept and the device itself.

The test results have been grouped according to three criteria: frequency to museum visits, nationality and experience with electronic guides. The first criterion was adopted to check the quality and quantity of information. The second one is useful to understand how much the choice of synthetic versus natural voice can affect the user's interaction with the electronic guide. The third criteria was chosen to analyse the reactions of those who had already had experience with electronic guides in museum visits with respect to those who had never used similar tools.

In the next diagrams we report the mean of the user ratings for each aspect considered and, when meaningful, the standard deviation.

5.2 Evaluation of quality of information given

These questions regard the information concerning the museum, its sections and the works of art. Users are grouped according to the frequency of museum visits. We have identified four categories: users who had never visited a museum before (3%); those who visit museums rarely (18%), often (66%) and frequently (13%).

Visitors who had never visited museums before particularly liked the information regarding the museum and the works of art (mean rating was about 8 on a scale of 0 to 10, with a standard deviation of 1.5), while they found information regarding the section less complete (mean rating about 7). One of them suggested providing additional information.

Users who rarely visited museums liked all the types of information provided by the guide (mean rating 7.5, standard deviation 1.5). One interesting suggestion regarded proposing alternative itineraries for the visitor to follow.

Frequent visitors liked the information provided and gave similar ratings. They suggested providing additional information on the living and working conditions of marble workers and on how marble is currently quarried. One of them commented: "I enjoyed being able to freely move about the museum, to stop where I wanted and to get related information".

As Figure 6 shows, very frequent visitors preferred the information regarding the sections of the museum. They suggested introducing videos on the life of marble workers and techniques for working marble.

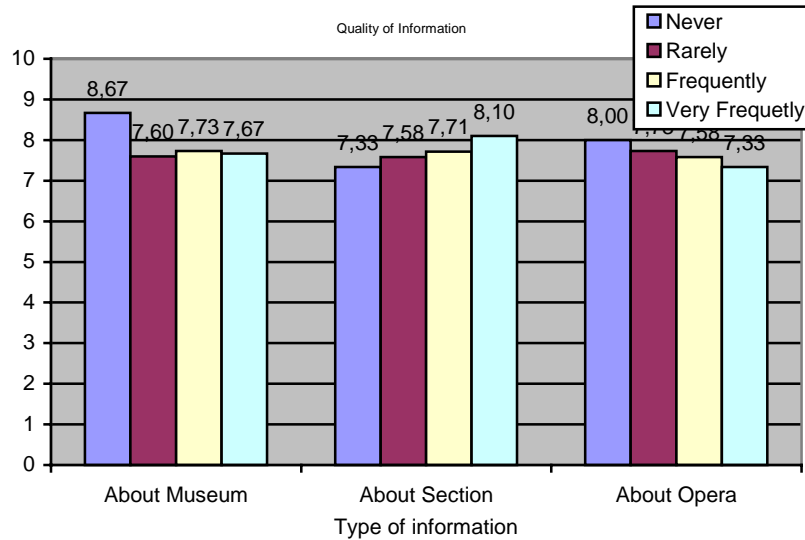


Figure 6: Evaluation of information given

5.3 Evaluation of quality of images, audio presentation and maps

In this case we consider the quality of audio comments and of the images used to show works of art and maps. As mentioned before, the only difference between the version for Italian visitors and foreign visitors was in the audio presentations: in the Italian version audio files were obtained by recording an actual woman's voice, whereas in the version for foreigners we used a synthetic English female voice. Thus, if we divide the tests between Italian and foreign visitors, we can study how the choice of using a synthetic voice affects the usability of the application.

Italian visitors enjoyed the presentations provided by the application and gave very high ratings (on average about 8). The audio presentations received high ratings with a mean of 9 and standard deviation of 1.25. They provided some suggestions such as the possibility of receiving more in-depth information on request and longer comments.

The ratings provided by foreign visitors were lower than the previous category. As can be seen in the diagram, the mean rating regarding audio presentations was 6 with standard deviation 2.39. The images and maps received better ratings (about 7.5 in both cases), though the standard deviations were still high (respectively 1.8 and 2.3). This may indicate that the problems with the audio presentations have somehow affected the evaluation of the other elements.

Some comments explicitly indicated that the audio presentations were considered monotonous, that is, lacking natural prosody and therefore sounding too "metallic".

Some suggested using a more human voice and adding also German and French to the languages supported.

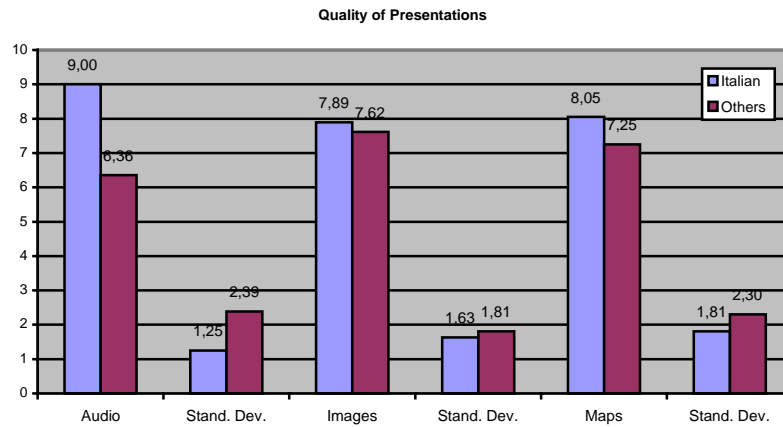


Figure 7: Evaluation of quality of images, audio presentation and maps

The next diagram can be useful to understand how much the quality of audio presentations has affected the use of the electronic guide.

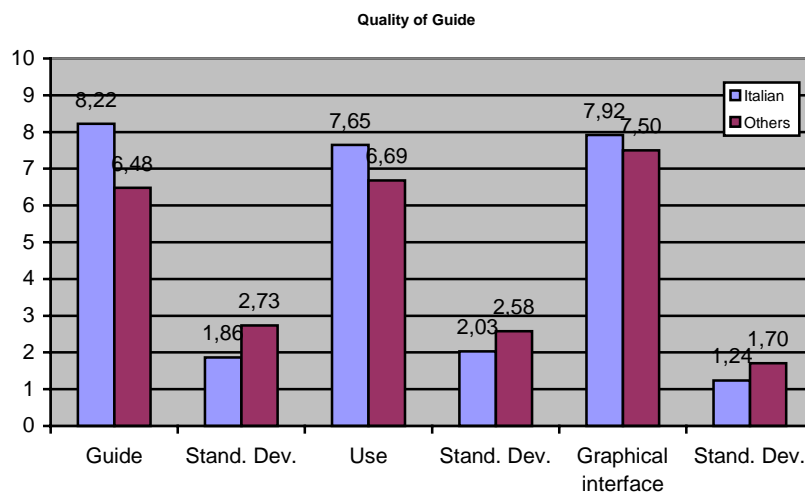


Figure 8: Italian and foreign visitors evaluation of guide

This diagram highlights the difference in evaluation between Italian users (who heard a human voice in the audio presentations) and the others.

Apart from the evaluation of the graphical interaction, the ratings related to the usability of the electronic guide are substantially different in the two groups of users.

5.4 Overall evaluation of our electronic guide.

In this case the questions concerned an overall evaluation of the electronic guide: its utility, usability, and user interface design. To analyse the results of the test we have divided the users who had previous experience with palmtops from those who used it for the first time.

The novices were the majority, as shown by the diagram (they were 65). They liked the user interface design more than the utility or usability of the application. The mean rating for these three parameters was similar (about 7) but the standard deviation was rather different (1.4 versus 2.5). One user commented “At the beginning some confusion, but then it was easy and useful”. Some suggestions regarded the possibility of adding videos and identifiers in the rooms in order to ease the visitor’s orientation in the museum.

The palmtop expert visitors were 27. They provided judgments similar to the other visitor category. One visitor commented “I liked to see works of art without having to stop to read the labels”. Some of them had some problems orienting themselves in the museum.

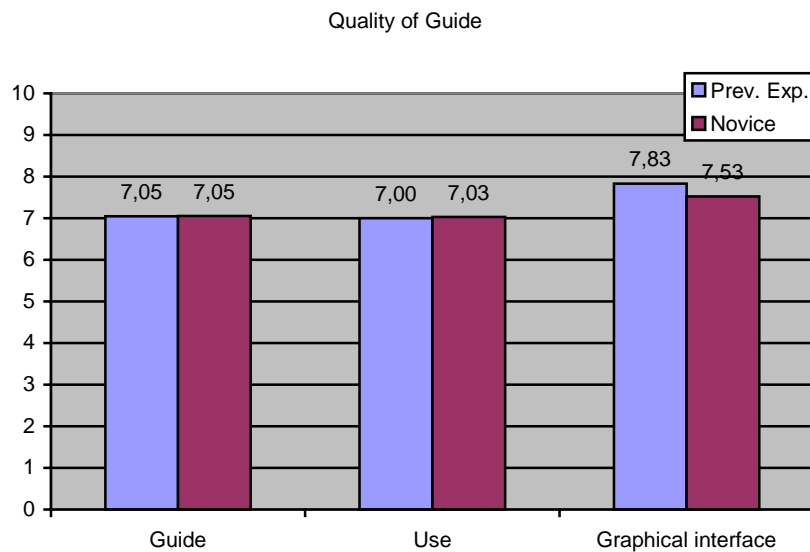


Figure 9: Novice and expert visitors evaluation of guide.

5.5 Evaluation summary

As we can see from the previous analysis, the aspect of our system that was rated most highly was the quality of information offered.

Other highly rated aspects were:

- the opportunity to visit museum by oneself.
- the exhaustive information given in a timely fashion.

Users' most frequent suggestions were:

- To give more information about the geological formation and working of marble, and the life of quarry-men.
- To supplement the information with video (e.g., about the working of marble).
- To use a human voice in the English audio presentation.
- To add presentation in other languages, especially French and German.
- To use arrows, colours and numbers to help users orient themselves in the Museum.

Another interesting observation was that most visitors preferred to use the guide without headphones because they wanted to share it in small groups (two or three people).

6 The Improved Version

In the new version we have taken into account the results of the user tests. In particular, we wanted:

- A different way to navigate that would allow users to better orient themselves;
- Better highlight how to get into and out of the rooms;
- Different ways to provide help information
- Support use of videos played through the PDA to enrich the user experience.

Part of the new design is described by the next CTT specification. Again, we consider the initial part of a user session. The main differences are: the general presentation regarding the museum is provided as soon as the user starts the session (*StartSession* task), we added a system task showing explanation of the icons used in the application (*ShowIconExplanation* task), the access to the section is not performed through the museum map, and the system provides explicit indication of the section position in the museum (*LocalizeSection* task) in order to help user's orientation.

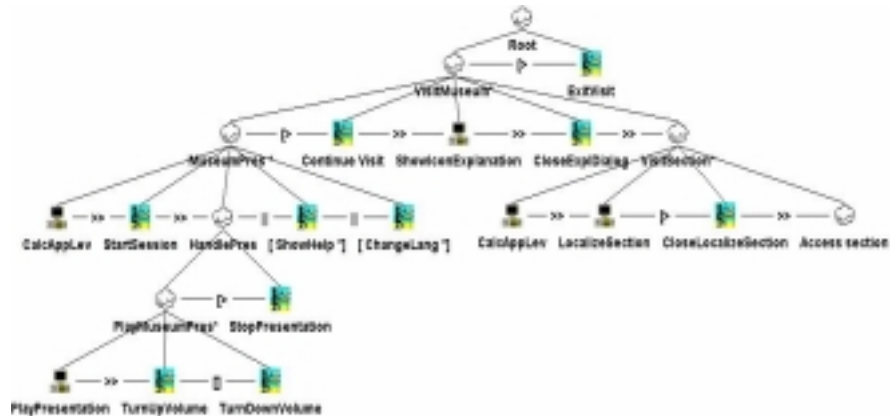


Figure 10 Part of the task model associated with the final design

The reason for these changes was that users always start their visit from a given point and that the structure of the museum imposes a linear path to the visit. Although visitors can at any time go up and down along this path and get disoriented, they cannot take a different route. Thus, we decided to have the PDA displaying where they are at the outset of the visit. Next, after having shown some basic information on how to use the application (such as the meaning of the icons), the application displays a map of the first museum section while providing audio information about it. Sections are made up of one or more rooms with common theme. Then, they can select a room and receive indications as to where it is, followed by its map with the possibility of selecting specific works of art and receiving related information. Figure 11 shows an example of this pattern of interaction from the starting point. Arrow heads on each door in the map of the room clearly highlight the suggested order of access. When they move to the next room they can just select the related door in the map and the new room map will appear. If a new section is encountered, then a general map with related information is first provided and subsequently a map of the selected room is displayed. One of the main differences with respect to the previous version of the application is that user access to information is no longer driven by the museum map. However, the overall museum map is still available on request in the event that visitors do not want to follow the path suggested by the physical museum structure.



Figure 11: Modality of navigation in the improved version.

7 Conclusions and Future Work

The new version is now available to the museum visitors. We are planning a new evaluation study with revised questionnaires and automatic analysis of logs of user interactions.

The system has been implemented with Embedded Visual C++ 3.0 as programming language and the Microsoft Foundation Class toolkit for the user interface development.

Technology for location detection is improving in terms of both cost and accuracy. Its introduction (for example with Bluetooth) will be investigated in the near future, at least to automatically identify the room where the user is.

Future work will be dedicated to identifying adaptive features of the application that can increase the users' interest without disorienting them.

Acknowledgements

We gratefully acknowledge support from the Carrara City Council and the Marble Museum and the Cameleon project (<http://giove.cnuce.cnr.it/cameleon.html>).

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