In&Out: A Context Aware Application Based on RFID Localization Technology

Alessandro Andreadis[1], Fabio Burroni[2], Pasquale Fedele[2]

[1] Department of Information Engineering, University of Siena, via Roma 56, 53100 Siena, Italy

[2] Agorà ICT, via Massetana Romana 12, 53100 Siena, Italy

Abstract. The wide adoption of wireless technologies has modified the typology of services that can be offered by information systems. Mobile users need ad-hoc information based on location and usage context, in order to minimize network usage and achieve service efficiency and effectiveness. This paper presents an information architecture providing context-aware and location-based contents to users exploring a museum and/or related archaeological excavations. While moving around, users are equipped with a client device and their position is precisely detected through RFID technology. Thus the system is able to suggest to the user specific multimedia contents. The system offers the user with a constant association between objects of interest and the place they were recovered from the excavation. Thus the visitor inside a museum room ("IN") can have a visualization or a hypothetical reconstruction of the place of recovery and, visiting the excavation ("OUT"), he/she can have information about the objects found.

1 Introduction

The integration of wireless communications with new technologies for detecting the location of users and objects in the physical space opens new perspectives in the fields of basic and applied research. Innovative information systems and communication services can be designed, developed and applied to different domains of interest, taking advantage of new wireless location-based technologies which allow to enhance user's satisfaction through the provision of augmented interactions. While for outdoor spaces there are many positioning methods [12] providing different accuracy (e.g., GPS, cellular based methods), more difficult is to determine user's position within tens of centimeters, especially inside buildings or even in a room.

Several efforts in the recent past were made to develop location-aware tourist guides [4], [8]. For example, in the HIPS project [1], [5] the combination of Infra-Red technology with an electronic compass allowed to achieve a great localization accuracy, at the expense of a complex arrangement of Infra-Red sensors in museum rooms. HIPS provided personalized and context-aware audio information, based on user movements inside a museum. Personalization issues with more sophisticated user

Andreadis A., Burroni F. and Fedele P. (2006).
In&Out: A Context Aware Application Based on RFID Localization Technology.
In *Proceedings of the 5th International Workshop on Wireless Information Systems*, pages 26-35

profiling mechanisms in the field of culture and tourism have been successfully experimented in several works [2], [7]. The PEACH project [10] proposes a multimedia museum guide on handhelds with mobile networking capabilities, in order to provide adapted interactions based on user interests and history of interaction.

In the system we propose here, personalization issues are combined with a very accurate location-aware mechanism, thus representing an added value for a mobile museum guide. Our innovative system architecture, based on the *Radio Frequency Identification* (RFID), allows the fruition of archaeological sites which are directly related with the museums containing the objects recovered from the archaeological excavations. Thanks to the adoption of wireless networks, the system supports user's mobility, allowing the user to freely move around an archaeological excavation or museum rooms while receiving location-based and context aware multimedia contents on his/her client device. A system prototype has been developed for the use on a tablet PC, but other devices with different capabilities (PDAs and in the near future Ultra-Mobile PCs) can be supported with suitable adaptations, mainly in terms of information content and user interface.

The client device, equipped with an RFID reader, transparently sends the user's position to the central system with a great accuracy (i.e., 10 cm), such as to get an appropriate reaction by the server in terms of downloadable objects about the work of interest the user is in front of.

In the following sections we present the main objectives and functionalities offered by this system, together with a general overview of its architecture and of the adopted technologies. We give detailed descriptions of the main blocks, client and server side, and of the RFID-based localization method; we describe how these blocks interact with the each other and with the content sources through wireless connections. Finally we present conclusions and future developments.

2 Objectives and System Overview

Did it ever happen you to visit a museum, admire an archaeological find, close your eyes and try to imagine the place where the find was discovered and how it was utilized? And did it ever happen you to visit an archaeological excavation and hear your guide saying that an extraordinary urn was discovered by the wall in front of you and that now this urn is preserved in a museum, together with its beautiful and rich funerary outfit?

We tried to give an answer to these questions by designing and implementing a wireless information architecture capable of virtually "transporting" outside (i.e., to the related archaeological excavation) the visitor of a museum, or, viceversa, of providing a virtual access to a museum during a visit to a related archaeological excavation. The basic idea is to create sensible environments through which the visitor plays the main role by interacting in a more participative way during the whole visit. In order to achieve this objective, the adopted technology should be at complete service of communication, allowing the designer to increase the quantity of information contents and to improve quality and effectiveness at the same time.

To this end, new visiting spaces have been designed, so that technological elements and informative contents are completely integrated with each other and with the surrounding environment. Thanks to the adoption of RFID, technology is neither directly recognizable nor constrained in a limited fruition space, but it is hidden in the elements that characterize the environment so as to become an integrated component. The visitor interacts with the surrounding environment in a simple and intuitive way, facilitated rather than hindered by technology. The objective is twofold:

· to create an information network able to communicate in environments of different dimensions, both outdoor (e.g., archaeological excavations) and inside buildings (e.g., museums), allowing users to freely move while receiving information about the visited environment; this implies the adoption of wireless technologies, such as Wi-Fi or GPRS/UMTS networks;
· to create multimedia contents (i.e., animations, video clips, images, sounds and voice) allowing to realize a logical correspondence between indoor and outdoor environments, between an object and the place of its recovery.

3 System Architecture

Our system, named "In&Out", is based on the consolidated client/server communication paradigm, but it introduces an innovative characteristic that allows the system to provide contents to the user in a continuous way, even with poor or absent network coverage. This peculiarity is very important, because many archaeological sites are located in areas not served by wireless networks (Wi-Fi and cellular networks). The proposed architecture is made up of the following elements (fig.1):

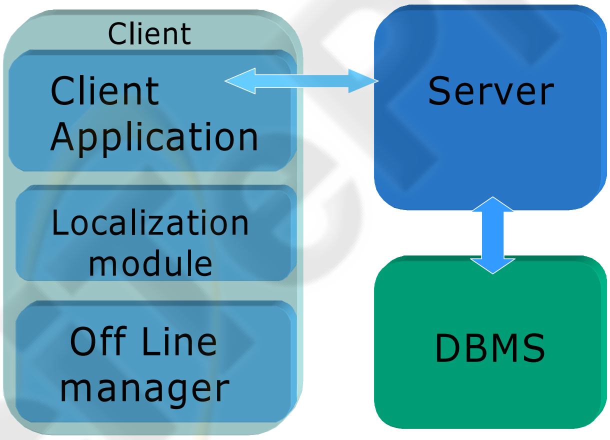

Fig. 1. General system architecture.

- the client device;
- the user localization module (integrated in the client device);
- the server;
- the Data Base Management System (DBMS)

3.1 User Localization with RFID Technology

The user localization module is based on Radio Frequency Identification technology. RFID systems are employed for automatic identification of distant objects, animals and individuals. RFID utilizes electromagnetic waves to read and write data on an electronic media named "*transponder*" or "*tag*" [6].

The tag is composed by a tiny memory chip with storage capabilities, combined with a miniaturized antenna and it can be read/written at short distance by an apposite reader/writer through electromagnetic waves. Each tag is identified by its own "ID": the ID is an alphanumeric string that is stored in the tag by the manufacturer and it is univocal, as different tags cannot share the same ID.

Power source is the main characteristic according to which tags are classified: there are passive, semi-passive and active tags [3], [9].

Our system utilizes passive tags and a reader of small dimensions (e.g., compact flash), with a reading distance of about 10 cm. In a passive RFID system, the tag hasn't an own power source, because the necessary energy for operation is provided by the reader, whose antenna generates a magnetic field. Such a field induces an electric current thus charging a capacitor in the tag. When the capacitor has accumulated enough energy, the tag is able to transmit a signal (e.g., its ID) to the reader. The communication between a transmitter and a receiver system in an electromagnetic field is always dependent on the relative position of the two antennas. In case of a "near field", the energy detected at the receiver depends on its angular orientation and on the distance from the transmitting antenna. In case of a "far field", the energy detected at the receiver depends on its distance from the transmitter.

The RFID system allows to keep management and maintenance costs significantly low, providing several advantages. Tags are of small dimensions, hence they can be fastened to other objects with simple clamping methods (e.g., fixatives) and can be easily replaced, even if their deterioration is improbable. For this reason they represent an optimal solution especially when located in outdoor spaces, because they do not need power supply for operating.

3.2 The Client

The client performs a twofold function: it provides the graphic user interface and it allows the user localization through the onboard RFID reader.

The communication with the server is based on HTTP protocol, consequently the client application is constituted by a web browser. Since we devoted particular attention to graphic, multimedia and usability features, the entire interface has been realized with Macromedia Flash technology. On one hand Flash allows to generate very appealing graphic interfaces, on the other it allows a very advanced management of all typologies of multimedia contents (text, video and audio). The Flash application, executed by the web browser's plug-in, communicates with the server through XML language [14]. XML documents received by the client contain all the necessary meta-information for downloading multimedia contents requested by the user.

The client deploys wireless links for communicating with the server: WiFi in case the visitor is inside a museum ("IN" modality), GPRS/UMTS (when available) in case he/she is visiting an archaeological excavation ("OUT" modality). During the "OUT" modality, the available bandwidth may be scarce and hence it is important to minimize network traffic. At this purpose, the client implements a *caching policy*, storing locally the downloaded multimedia objects requested by the user during previous interactions. In fact it is likely that a user requests more times the same contents; in this case the client's cache can directly provide the requested objects without loading the network.

As previously specified, the client embeds an RFID reader for managing user localization. The reader is interfaced to the Flash application through a software layer developed with ActiveX [11] and through JavaScript technology. The client architecture is depicted in figure 2.

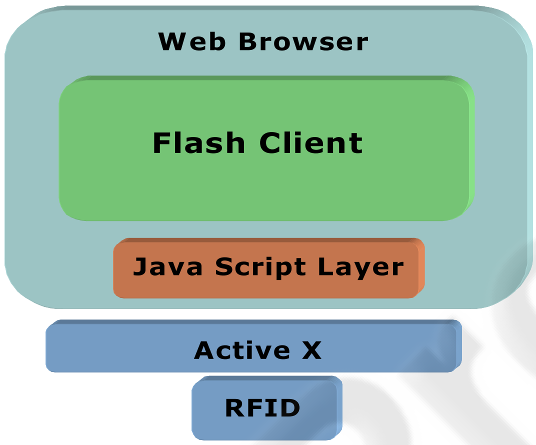

Fig. 2. Software layers in the client.

The ActiveX component, realized in C language, constitutes an abstraction layer towards the onboard RFID reader; more specifically, it provides the above layer with simple functions for handling connection and for reading the tags. The JavaScript layer implements the mapping between the functionalities given by ActiveX and the Flash application.

When the client device passes near a tag, such tag is detected by the RFID reader, thus generating an event. This event communicates the ID of the detected tag to the Flash application. Tags can be associated to different objects that are located inside a museum or in an excavation. For example, inside a museum, a tag can be linked to a work of art, to a painting or a casket, but also to the entrance of a room.

The Flash application automatically sends to the server an HTTP request message posting the ID of the detected tag that implicitly determines the user position. The server's HTTP response message is an XML document that contains information (i.e., URLs) on the multimedia contents associated to this tag and available on the server (see fig. 3).

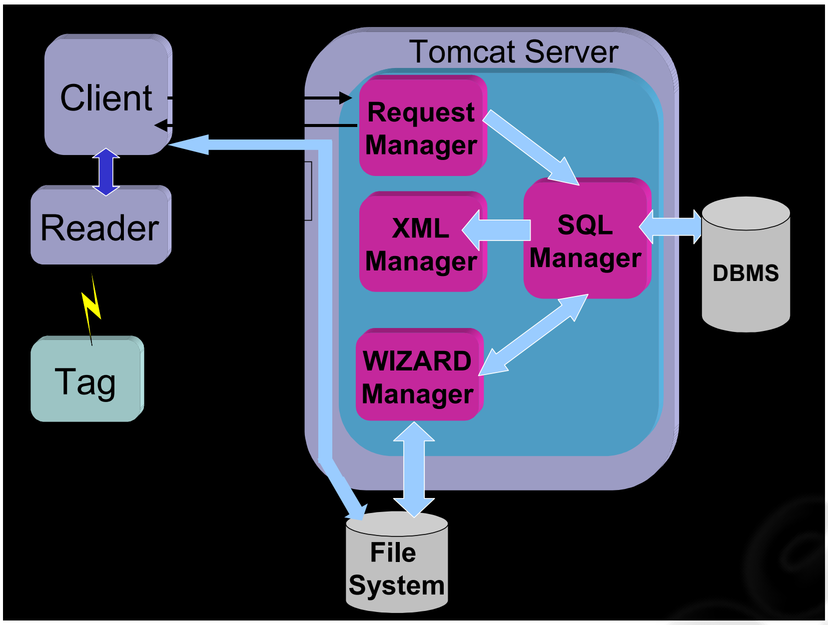

Fig. 3. Server architecture and interactions with the client.

The client we adopted in the working system is a tablet PC provided to the user at the beginning of his/her visit, but also a PDA can be used, with more limited capabilities.

3.3 The Server

The client device interacts with an information server through a wireless access, that, in case of a museum ("IN" modality) is provided by a Wi-Fi network and, in case of an outdoor excavation ("OUT" modality) can be offered by a GPRS or UMTS network. The server is made up of a web application entirely developed in Java and it represents the core architecture, implementing the following functions:

- identification of user's location;
- delivery of multimedia contents;
- monitoring of the visit;
- handling of multimedia objects.

The user position inside the museum and on the excavation of the archaeological site is represented in the system by the location of the detected tag. The matching between the detected tag's ID and the physical location of the user is stored in the DBMS. The client detects the tag's ID and it sends it to the server through an HTTP request message, as shown in fig.3. The server gets from the DBMS the association between this ID and its physical location, together with all the multimedia contents which can be of interest to the user during that particular moment of the visit. In fact, the DBMS contains all the tags IDs, and also the links (i.e., URLs) to the multimedia objects associated with each tag.

Moreover, the server continuously monitors the activity of the visits, storing not only the personal data of users, but also information on user's activities during his/her visit, such as the followed path, the works of art in which he/she was interested, timings, etc...In this way it is possible to know users behaviors and this can be the starting point for implementing user profiling mechanisms, with the aim at providing personalized interactions with the system and its multimedia contents. The system is able to deliver context-aware information, where the context is extracted by the client position (IN or OUT modality, user location, work of art he/she is visiting,...) and by other monitored features (time spent in front of a work of art, history of the visit, time to closure of the museum, previous interactions,...).

Multimedia objects hosted on the server are images, text, photos and video which can be delivered to the client on demand through the HTTP protocol. The pages are currently developed for best rendering on 11 inches displays with a resolution of 1024x768 pixel and the graphic interface has been specifically designed for this type of application. Anyway, in future developments the software architecture will be capable to perform automatic adaptations of information contents to the characteristics of different devices (e.g., PDAs) and to user preferences and requirements, following the same approach of the PALIO project [2].

The server has been realized with Servlet technology, while the server engine hosting the application is implemented using Tomcat 4.1 [13].

3.4 The Wizard

A Content Management System based on a Wizard has been developed in order to allow a simple maintenance of the server through simple updating operations which can be executed locally or remotely. The Wizard, realized with *Java Server Pages* (JSP), is a guided procedure that allows an administrator to easily update the system without owing specific informatics skills. It permits executing uploads of multimedia contents, specifying links between works of art and multimedia objects, recalling collected data about previous visits. The main characteristic of the Wizard relies on the possibility to execute it remotely. In fact its interface is realized in HTML and thus it can be accessed through a common web browser. Hence, it is not necessary for the administrator to be in front of the server to update the system with new multimedia contents.

3.5 The DBMS

A fundamental element of the whole architecture is the DBMS. The DBMS is a relational database. It has been implemented using MySql, due to its good performance. The Data Base has a complex structure, because it handles many different aspects: users, visits, works of art, multimedia objects.

First, it allows to link the tag's ID to works of art, and works of art to related multimedia contents. The DBMS refers to such contents through appropriate URLs;

actual contents (e.g., audio and video files) are stored in a file server. Secondly, the DBMS contains user's personal data as well as other information about his/her visit, such as the works he/she examined and the time spent in front of them. All this data are very important for the development of the software module providing content personalization.

The DB is designed in such a way to allow the creation of links between works of art belonging to different museums. This functionality allows to enrich the visit with multimedia contents related to the objects of interest which are exhibited in other museums, thus making it possible to realize an "inter-museum" guide.

3.6 Off-line Operation

Some contexts may require the client to work in stand-alone mode, without real-time interactions with the server. Possible reasons can be the location of the archaeological site, characterized by low or even absent network coverage, or even management and installation costs. In such cases, the client given to the user at the beginning of his/her visit is endowed with an internal business logic, replicating onboard part of the server functionalities, of the DB and of multimedia contents. Hence, in case of absence of network coverage, the client contacts its internal business logic instead of the main server. If needed, an automatic synchronization procedure has been appositely envisaged in order to update data between client and server.

Although it is an interesting feature, the off-line mode represents just a solution for difficult settings. During off-line operation, some important characteristics are lost, since the limited processing capabilities of handheld devices do not allow to implement the full system onboard. Hence, the system looses effectiveness in terms of user profiling features, on-line monitoring of the visit and portability.

4 Operating Modality

At the beginning of a visit, the client is given to the user at the entrance of the museum. The device consists in a tablet PC with touch screen (through a stylus pen), presenting the user with a registration form to be filled with name, surname and email contact. After the registration procedure, the visit can begin. During the visit, the user passes near several points of interest, marked by visible labels that hide RFID tags. By approaching the client's antenna to the label, the tag is detected and hence the user's location. This event is notified to the user through the appearance of a miniature in the vertical bar positioned on the left part of the interface (see figure 4). The selection of this miniature produces in the central window (content window) the information on the point of interest (i.e., work of art) in front of him/her. The superior part of the content window reports the icons related to multimedia contents associated to the work of interest, the inferior one gives information related to the external context (i.e., the archaeological excavation). This subdivision of the interface allows to be always in control of the situation in terms of associations between IN and OUT spaces. During the visit the user can mark his/her "favourite" objects and take notes with a stylus pen; at the end, multimedia contents associated to the favourites can be stored on a CD-ROM that is given to the user, or they can be sent him/her via email upon request. In such a way the user can live again the experience at home, perhaps examining with more details the most interesting works.

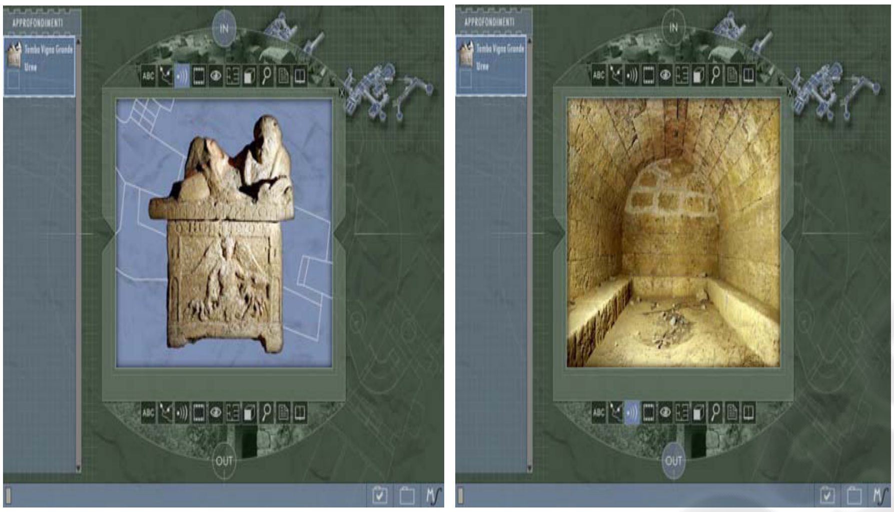

Fig. 4. The “IN” and the “OUT” user interfaces on the client device.

5 Conclusions and Future Work

This paper has presented an innovative information architecture for providing specific contents to mobile users on the basis of their location. RFID technology has been adopted for achieving a highly accurate localization within tens of centimeters and it has been integrated in palmtop devices given to users at the beginning of a visit to a museum or to an archaeological excavation. Physical movement is the main input, leading the interaction modality between the visitor and the system. While moving around, the user can listen to commentaries related to the objects he/she is examining, enriched by other media contents such as video-clips or other sounds that help reconstructing the ancient atmosphere. Other interactions can be activated upon user’s request through a touch screen, with a stylus pen.

Although not a completely new idea, with respect to other approaches [15] this RFID/context-aware system presents additional features which contribute to enhance user experience: the integration with wireless networks in support of user’s mobility around the museum/excavation area, the continuous monitoring of user’s activity during the visit, the off-line modality in case of poor network coverage.

The developed prototype has been successfully implemented and tested in Tuscany, specifically in the archaeological area and related museum of the Murlo village, characterized by many Etruscans finds. However, several users (i.e., visitors and museum operators) pointed out that the tablet PC adopted in the first prototype was too big and heavy, while a smaller device like a PDA could be more suitable for enhancing user experience, even at the cost of display size and graphic resolution.

Future work is focused towards the implementation of dynamic adaptations to different devices (PDAs and Ultra-Mobile PCs) and the provision of collaborative features, allowing users to take notes on the client and to share their experience.

References

1. Andreadis, A., Benelli, G., Bianchi, A.: Audio Augmenting Physical Navigation in Art Settings. Proc. of International Conference on Universal Access in Human-Computer Interaction (UAHCI), New Orleans, Louisiana, 5 -10 August 2001, 222-226.
2. Andreadis, A., Fedele, P., Giambene, G., Santoro, J.: Service Adaptation and Personalisation in the PALIO Project. Proc. of International Conference on Universal Access in Human-Computer Interaction (UAHCI), vol.4, Crete, Greece, 22-27 June 2003, pp.294-298.
3. Battezzati, L., Hygounet, J.L.: RFID, Identificazione Automatica a Radiofrequenza, Tecnologie e Applicazioni. HOEPLI, Milano (2003).
4. Baus J., Krüger A., Wahlster W. A Resource-Adaptive Mobile Navigation System. Proc. of the 7th International Conference on Intelligent User Interfaces. San Francisco, CA, 2002.
5. Benelli, G., Bianchi, A., Diligenti, M.: A Position Aware Information Appliance. Proc. of EUSIPCO 2000, Tampere, September 2000.
6. Chang, K.: RF and Microwave Wireless Systems. John Wiley & sons, New York (2000)
7. Chou, S.C., Hsieh, W.T., Gandon, F.L., Sadeh, N.M.: Semantic Web Technologies for Context-Aware Museum Tour Guide Applications. Proc. of 19th IEEE International Conference on Advanced Information Networking and Applications (AINA'05), Taipei, Taiwan, 28-30 March 2005, pp709-714.
8. Cigliano, E., Monaci, S.: Multimuseum: a Multichannel Communication Project for the National Museum of Cinema of Turin. Proc. of Museum and the Web 2003, Charlotte, NC, March 2003.
9. Finkenzeller, K.: RFID Handbook: Fundamentals and Applications in Contactless Smart Card and Identification. John Wiley & Sons, Chichester (2003).
10. Graziola, I., Pianesi, P., Zancanaro, M., Goren-Bar, D.: Dimensions of Adaptivity in Mobile Systems: Personality and People's Attitudes. Proc. of Intelligent User Interfaces (IUI05), San Diego, CA. January 2005.
11. Mueller, J.P.: ActiveX from the Ground Up. Osborne McGraw-Hill, Berkeley (1997).
12. Sun, G., Chen J., Guo W., Liu, K.J.R.: Signal Processing Techniques in Network-Aided Positioning: a Survey of State-of-the-Art Positioning Designs. Signal Processing Magazine, IEEE, Volume 22, Issue 4, July 2005: 12-23.
13. The Apache Software Foundation: Apache Tomcat. http://jakarta.apache.org/tomcat.
14. W3C Recommendation, Extensible Markup Language (XML), http://www.w3.org/XML/
15. Yatani, K., Sugimoto, M., Kusunoki, F.: Musex: A System for Supporting Children's Collaborative Learning in a Museum with PDAs. Proc. of 2nd IEEE International Workshop on Wireless and Mobile Technology in Education (WMTE'04), Jhongli, Taiwan, 23-25 March 2004.