RFID-based solutions for user profiling in interactive exhibits

Gianpaolo D'Amico, Alberto Del Bimbo, Andrea Ferracani, Lea Landucci, Daniele Pezzatini, Luca Santi
MICC - Media Integration and Communication Center
University of Florence, Italy
[damico, delbimbo]@dsi.unifi.it, [andrea.ferracani, daniele.pezzatini]@unifi.it, [lea.landucci, lukesan7]@gmail.com

***Abstract*—In this paper we present a work-in-progress interactive exhibit for the museum of Onna, a little town near to L'Aquila (Italy), almost completely destroyed by the earthquake of April 2009. The installation will be developed as an environment in which visitors of the museum can interact with a natural interaction system and then discover the history of the disaster via rich multimedia contents. Visitors are detected through the adoption of an RFID-based technology, which allows to store their interaction history and build an interest profile used to enrich the experience. Different scenarios have been implemented and tested in order to evaluate the effectiveness of the proposed solution.**

***Keywords*-Natural Interaction; Interaction Design; Location Awareness; RFID; Real-time Location; User Interfaces; Interactive Museums; Multimedia Installations.**

I. Introduction

Under the guidance of the Onna Onlus (non-profit organization), the community of Onna is trying to gradually rebuild the town destroyed by the earthquake of April 2009 and to raise awareness among local citizens and visitors of the work of reconstruction, properly communicating the past events and the efforts invested. With these ambitious purposes, they are building a museum in memory of Onna in which our system will be housed.

The intention of the curators is to adopt multimedia systems and natural interaction principles [16] to present a large collection of information in digital format related to the exhibition: video interviews with people directly involved in the disaster, images of the town before and after the earthquake, maps representing the alterations of the geography of some places in Onna.

We are going to exploit recent solutions in natural interaction, location awareness and RFID-based techniques in order to develop an interactive multimedia system able to achieve these purposes.

The reminder of this paper is organized as follows. In section 2 we present related work in the field of interactive museums and RFID-based technologies. In section 3 we propose the basic concepts regarding the work in progress, explain the architecture of the developed prototype exhibit and the user experience that has been designed. In section 4 we present the experiments performed with RFID-based technology to evaluate the effectiveness of the proposed solution and finally conclusions and discussion about the future work are presented in section 5.

II. Previous work

Nowadays the concept of museum is not more perceived as a pure container of artwork, with exhibition and information purposes only, but it is evolving to meet the needs of its visitors, making their experience become unique. Visitors are increasingly anxious to know, see, hear, touch and collect as much information as possible in a short time exploiting innovative technology. Moreover, they want to be engaged and entertained.

A. Interactive multimedia museums

The affirmation of social networks and the related evolution of the Internet (web 2.0) are concerning networks of people rather than of computers; on the other hand the progressive spread of multi-sensor solutions and advanced technologies of communication, capable of linking each visitor with the surrounding objects, feed the so-called *Internet of things* [17]. These are the ingredients of the modern museum challenge. That is why, in recent years, the purpose of museums has shifted from merely providing static information of artworks to personalized services for visitors worldwide [1].

From its early roots in the WebLouvre by Nicolas Pioch in 1994 [2], the state-of-the-art in interactive multimedia for enhanced museum experiences is visibly growing up. In Figure 1 two examples of on-line multimedia systems for interactive museum virtual access are shown. The San Francisco Museum of Modern Art (SFMOMA) [11] allows users to browse an extensive virtual catalog of works and Google Art Project [10] uses Google StreetView technology to build an interactive, virtual and explorable 3D model of 17 physical museum exhibitions.

Many museums offer even in-site multimedia tours, providing natural user interfaces for visitors to use while exploring the exhibits, both exploiting interactive surfaces for large audience (e.g. multi-touch tables, walls or carpets) and personal devices such as smartphones or tablets. These tours strengthen the exhibitions by providing visitors more informed enjoyment and knowledge, hence greater engagement with the artworks [5],[25]. The great challenge is to provide a personalized and extended museum experience for visitors in immersive artistic environments [6].

The theme of in-site personalization enjoys a long history in multimedia information analysis and in particular in the

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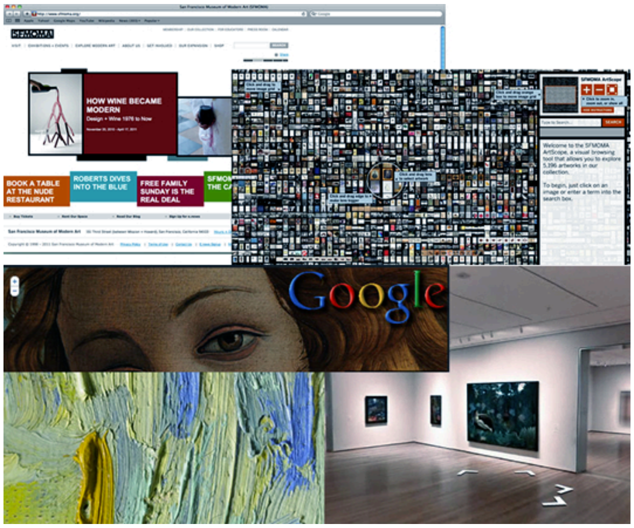

Figure 1. Modern multimedia museums give users the ability to view the collection online (upper panel from the SF MOMA) and to plan and customize their visit (lower panel, a virtual museum tour using Google StreetView technology).

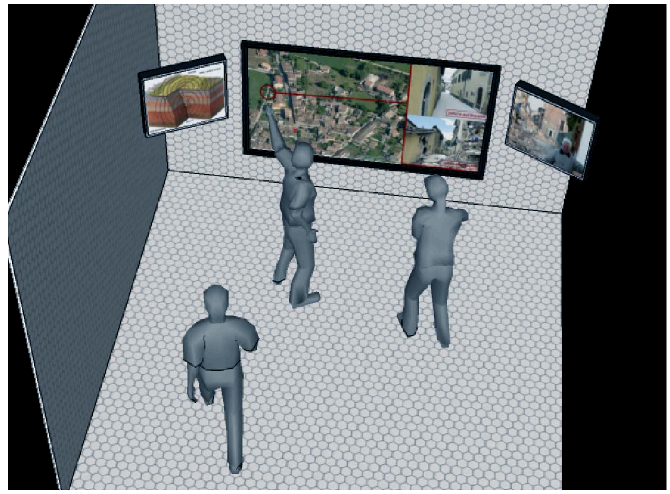

Figure 2. The Onna exhibit: a multimedia environment in which multiple users can interact with a natural interaction system.

realm of interactive multimedia museums [3],[4]. Through the joint use of interactivity and instruments for analyzing how people move around the exhibition rooms, the museum can transform visitors from mere explorers of artwork in active orchestrators of the very experience at hand: thus the new technologies turn the museum's rooms into body-driven interactive multimedia narrative spaces [7].

B. *RFID-based solutions for museums*

RFID technology can be exploited to large and diversified potential areas of application and for this reason it is classified as general purpose technology. It is usually exploited for electronic passports, automated access control ticketing, document management and their preservation in archives and libraries [12],[13].

There are also interesting experiments in museum contexts, not only for document management, but also for the *proximity-based interaction* in order to analyse the user physical behavior near an object. A visitor equipped of a mobile device can receive - in a completely automated way - flows of multimedia information, simply approaching one of the works of art [14], [15]. The visitors, therefore, no longer actively perform a search process: their proximity to the work of art triggers a dialogue between the mobile device and the information stored in a database, providing the contents of interest. However, such approach moves the visitor's focus of attention from the work of art to the display of the mobile device. Our idea is to exploit such technology avoiding the degradation of the work of art fruition experience: the proximity between RFID tag provided to the visitor and the piece of art allows the use of not intrusive profiling methods.

III. The system

Our work aims to create a novel solution for the design of interactive environments for modern museums and exhibitions. The first exhibit prototype consists of an immersive space in which Computer Vision solutions allow people to interact seamlessly with multimedia contents (videos, images and audio) representing the tragic events occurred to the town of Onna during the earthquake. The objective is to build a dedicated room in the museum of Onna in which people could live a multisensorial experience.

Users can enter the room after registering at a desk to receive a personal RFID tag which will be used as an identifier during the visit. The space is equipped with large sized screens on the walls to represent visual contents and high-quality speakers to convey audio contents (see fig. 2). A great importance is given to the possibility for multiple users to interact at the same time and independently with the system.

Finally, a new direction for our experimentation is outlined by the possibility of recording the activity of users while interacting with the system, in order to build a personal profile containing the history of their visit. This personal *bag of information* can be used with mobile devices to exchange data with location awareness systems (i.e. GPS) and then present related multimedia contents when users are near to some important places in Onna.

A. *Architecture*

The system is mounted in a rectangular room (4,5m x 3,0m) which has been darkened (lights devices disturb screens projections) and made soundproof (external sounds disturb listening of audio contents). It is composed of the

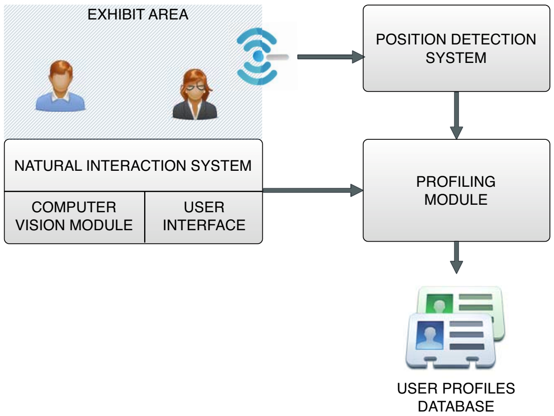

Figure 3. The system architecture: visitors of the museum in the exhibit area can interact with a natural interaction system by a computer vision module which is responsible for processing human gestures and present multimedia contents via the user interface. All the information about the location of the visitor are analysed by the position detection system. A profiling module extracts data from those two systems in order to build a database of profiles of interest for each user.

Figure 4. Metaphor for the user interface: images representing the areas of Onna before the earthquake are visualized via user interaction over a base image showing a current view of the town.

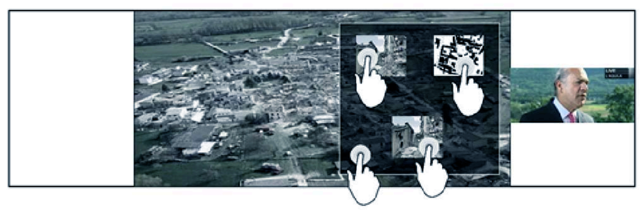

Figure 5. Example of navigation: users trigger active areas in the central display in order to visualize contents on the lateral screens.

following elements: the natural interaction system, the position detection system and the profiling module (see fig. 3).

The natural interaction system has two objectives: to detect gestures of users and then to present information in order to allow the navigation of multimedia contents. It is composed of a central double display made with short throw projectors, two stereoscopic cameras on the top and two lateral displays. The stereoscopic cameras observe in real-time the interaction space, providing information about presence, location and actions performed by the user's hands. Gestures of the users in front of the central screen are captured and then processed by a Computer Vision module based on diffuse illumination technique [16] as to perform the interaction. In order to make vision sensing reliable and robust to changes in the environment, the cameras work in the near infrared spectrum and the scene is illuminated with NIR lights.

The position detection system provides a solution for identifying every person interacting with the natural interaction system. At the end the profiling module processes all the data extracted from the natural interaction and detection systems to populate a database containing the history of all the visitor activities in order to build a profile of his/her interests.

B. *User experience*

The user interface features natural interaction in order to allow users to access and consult multimedia contents related to different areas of the town of Onna. The concept proposed for the interface was inspired by the educational game book published in the seventies about the devastation of the town of Pompei, after the eruption of Vesuvius in 79 B.C.. The structure of the pages of the book is composed of images of the destroyed Pompei which can be overlapped with images of the town before the eruption.

Our idea is to recreate a similar metaphor and use a background picture of the town of Onna after the earthquake, so that the user can interact with some areas of the image and see them as they were before (see fig. 4). In addition for each area it is possible to visualize multimedia contents about history, architecture and life of the town, like video interviews, images and maps. Such contents are visualized in the lateral audio-video displays in order to avoid information overload on the main screen (see fig. 5).

The history of the navigation through the multimedia contents is seamlessly associated to the user mobile device via RFID tags. Hence during their visit to the town of Onna people can use these information to visualize/listen multimedia contents related to a particular area or have suggestions about interesting places to visit.

IV. RFID EXPERIMENTATION

An indoor location system has to be exploited in order to obtain the association between the user and the content visualized during the interactive session.

A number of technologies were analyzed with this purpose: Wi-Fi [19], UWB [22], Bluetooth [23], active RFID [21]. Unlike *active* technologies, RFID passive tags have several advantages like cost, size and weight. Active devices must be powered by a battery and are more or less the same weight and size as a modern smartphone. Instead, passive RFID devices are single, unpowered microchip (or tag) of a few centimeters in area and of negligible thickness: they are small enough to fit into a practical adhesive label or plastic badge. Since they don't need power supply, the cost of producing such tags is very low and they have an indefinite operational life [18].

A. *RFID-based profiling module*

Each visitor is equipped with an RFID tag in order to have an unique identifier. Due to the degradation of radio frequency signal by the human body, we had to find solutions to keep the tag exposed to antennae signals. We tested two scenarios with different positions of the RFID tag respect to the body of the visitor: *front-vertical* and *top-horizontal*. For each solution we built two objects to contain the RFID card and hold it still while the visitor is moving in the space of the exhibit. For the front-vertical configuration we built a typical rectangular cardboard badge attached with a collar to the neck of the visitor; for the top-horizontal configuration we attached the RFID card over a flexible plate in PVC to be weared on the head of the visitor, as a part of the structure of a prototypical audio headphone.

In a first phase of experimentation, we used a simulated scenario constructed in our laboratory. This scenario has been designed to simulate an interactive wall about 3m wide, on which the interactive representation of Onna is projected. In particular, we tested UFH (865/928 MHz) tags, which support remote identification of visitors at up to 10m. RFID antennae communicate with readers in order to determine the signal strength of each tag present in the field, from which we want to estimate the position of a visitor in front of the interactive system [24].

Given that the size of the screen allows the interaction to a maximum of two simultaneous visitors, we divided the environment into two areas of identification. The idea is to read the Received Signal Strength Indicator (RSSI) [20] from two antennae pointing toward the area where users equipped with RIFD tags will stand during their interaction. An SVM classifier has been used in order to determinate if the tag is located in the left or right area. This solution makes the system less sensitive to noise on antennas readings and also easy to be re-trained and re-configured in different scenarios. For each scenario, we recorded a set of RSSI values from the two antennae placing the tag in different distances, taking samples every 20 cm, and we used this as training set for the classifier.

In both scenarios, the kernel used is a Gaussian radial basis function and the parameters have been obtained performing a cross validation with the recorded values.

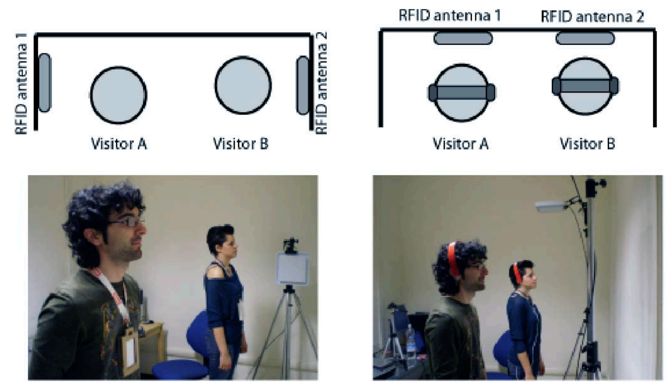

Figure 6. Testing scenarios: on the left the Front-vertical badge-holder configuration and on the right the top-horizontal headphones one.

B. *Evaluation of RFID-based solution*

We analyzed 15 test sessions in order to evaluate the robustness of our method and first results are encouraging. We tested two different scenarios (see fig. 6) with both badge-holder and headphones with two users at a time performing several trajectories and triggering different multimedia contents. In this way we have been able to evaluate the effectiveness of our detection methods at different levels: the classifier and the profiling module.

Front-vertical badge-holder scenario:
average Classifier error rate: 17.45%
average Profiling Module errore rate: 4.56%

Top-horizontal headphones scenario:
average Classifier error rate: 8.95%
average Profiling Module errore rate: 2.04%

The error rate of the SVM classifier is higher than that of the profiling module because the former works in a punctual way using antennae readings every single second; for the latter we exploited a voting method based on the last ten results of the classifier. Table in fig. 7 shows the results of a sample testing session in the badge-holder scenario. User A (with tag ID 38) stand on the left and user B (with tag ID 83) on the right. Both users activate different multimedia content, populating the users-content association table. The extracted data show a classifier error rate of 13.89% and a profiling module error of 0%.

Results indicate that the use of headphone reduce the error rate and make the system more reliable: this is due to the position of the RFID tag which prevents the absorption of the signal from the user's body.

Position detection of user A

ID Tag	RSSI 1	RSSI 2	Pos.	Time
38	59		Left	0
38	45		Left	2
38	45		Left	3
38	45	57	Left	5
38		53	Right	6
38	51	53	Left	8
38	49	53	Left	9
38	51	55	Left	11
38	51	53	Left	12
38	51	55	Left	14
38	51	55	Left	15
38	49	61	Left	17
38	49		Left	23
38	47		Left	25
38	47	59	Left	26
38	47		Left	29
38	47		Left	30
38	49		Left	33
38	49		Left	34
38	49		Left	36
38		49	Right	37

Position detection of user B

ID Tag	RSSI 1	RSSI 2	Pos.	Time
83	59	55	Left	13
83	57	49	Right	14
83	49	61	Left	17
83	55	43	Right	18
83	55	45	Right	20
83	59	45	Right	21
83		51	Right	24
83	59	49	Right	25
83	55	53	Left	27
83		47	Right	29
83	59	47	Right	31
83		49	Right	33
83		49	Right	35
83		49	Right	37

User - content association

ID Tag	Position	Time	Content pressed
38	Left	29	cnt1
83	Right	36	cnt2

Figure 7. Sample testing session with two users in the front-vertical badge-holder scenario.

V. Conclusion

This paper presents an interactive exhibit to represent multimedia information about the museum of the town of Onna in Italy.

Installed in an indoor environment inside the main exhibition, the proposed system detects gestures and movements of multiple users and present images, audio and video contents according to the principles of natural interaction. Each user is equipped with a RFID tag in order to build an association between his mobile device and the contents of the exhibit, so that he can reuse them while visiting the places of the town.

Two different RFID scenarios have been developed and tested in experiments, in order to evaluate the effectiveness in detecting the user position, thus achieving a more efficient association between the RFID tag and the history of user interaction with the system. Experimental results demonstrate the effectiveness of the proposed solution.

Future work will address an extended experimental evaluation with different users scenarios and RFID configurations, as well as an expansion of solutions for presenting multimedia content related to the exhibition via the mobile devices.

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References

[1] Bowen, J.P. and Filippini-Fantoni, S. *Personalization and the web from a museum perspective.* Proceedings of the Museums and the Web Conference (MW04), 2004.

[2] http://www.ibiblio.org/wm/

[3] Brusilovsky, P. and Maybury M. T. *From adaptive hypermedia to the adaptive Web.* Communications of the ACM, 45(5), 30-33, May, 2002.

[4] Pechenizkiy, M. and Calders, T. *A Framework for Guiding the Museum Tour Personalization.* In: PEACH, 2007.

[5] Sakamura, K. *Peized digital museum assistant.* In: Digital Museum, 2003.

[6] Wang, Y., Aroyo, L., Stash, N., Sambeek, R., Schuurmans Y., Schreiber, G. and Gorgels, P. *Cultivating Personalized Museum Tours Online and On-Site.* Interdisciplinary Science Reviews, Vol. 34, No. 2, Pages 141-156, June, 2009.

[7] Sparacino, F. *Scenographies of the past and museums of the future: from the wunderkammer to body-driven interactive narrative spaces.* ACM Multimedia, 2004.

[8] Tesoriero, R., Gallud, J. A., Lozano, M., Penichet, V. M. R. *A Location-aware System using RFID and Mobile Devices for Art Museums.* Fourth International Conference on Autonomic and Autonomous Systems, 2008.

[9] Chandan Maity, M Vijaybabu *RTLS in Passive RFID System.* Proceedings of ASCNT, 2009.

[10] http://www.googleartproject.com/

[11] http://www.sfmoma.org/

[12] Garfinkel, S. and Rosenberg, B. *RFID : Applications, Security, and Privacy.* Addison-Wesley Professional, July 6, 2005.

[13] He, W., Tan, E.L., Lee, E.W., Li, T.Y. *A solution for integrated track and trace in supply chain based on RFID and GPS.* Emerging Technologies and Factory Automation, 2009.

[14] Mody, A., Akram, M., Rony, K., Aman, M.S., Kamoua, R. *Enhancing user experience at museums using smart phones with RFID* Systems, Applications and Technology Conference, LISAT '09. IEEE, 2009.

[15] Yo-Ping Huang, Shan-Shan Wang, Sandnes, F.E. *RFID-Based Guide Gives Museum Visitors More Freedom.* IT Professional, 2011.

[16] Baraldi, S., Del Bimbo, A., Landucci, L., Torpei, N. *Natural Interaction.* Encyclopedia of Database System, Springer, 2008.

[17] Ashton, K. *That 'Internet of Things' Thing.* RFID Journal, 22, 2009.

[18] Want, R. *An introduction to RFID technology.* Pervasive Computing, IEEE , 2006.

[19] Qiuxia Chen, Dik-Lun Lee, Wang-Chien Lee. *Rule-Based WiFi Localization Methods.* Embedded and Ubiquitous Computing, 2008.

[20] Junhui, Z., Yuqiang, Z., Mengjie, Y. *Research on the Received Signal Strength Indication Location Algorithm for RFID System.* Communications and Information Technologies, ISCIT '06, 2006.

[21] Tesoriero, R., Gallud, J., Lozano, M., Penichet, V. *Using active and passive RFID technology to support indoor location-aware systems.* IEEE Transactions on Consumer Electronics, 2008.

[22] Yuechun Chu, Ganz, A. *A UWB-based 3D location system for indoor environments.* International Conference on Broadband Networks, 2005.

[23] Gwon, Y., Jain, R., Kawahara, T. *Robust indoor location estimation of stationary and mobile users.* Twenty-third AnnualJoint Conference of the IEEE Computer and Communications Societies, 2004.

[24] Chandan Maity, M Vijaybabu. *RTLS in Passive RFID System.* Proceedings of ASCNT, 2009.

[25] Colombo, C., Del Bimbo, A., Valli,A. *Visual capture and understanding of hand pointing actions in a 3-D environment.* IEEE Transactions on Systems Man and Cybernetics, 2003.