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Article

A sustainable ambient intelligence enabled management model

A Sustainable Ambient Intelligence Enabled Management Model for the Valorization and Revitalization of Cultural Heritage

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Abstract

Information and Communication Technology (ICT) pervasiveness is changing the visitors' expectation in the fruition of cultural heritage assets (e.g. artefacts, buildings, monuments).

While owners of such assets have to face new challenges in the protection, conservation, management and active promotion of places they are responsible for, pervasive ICT systems (e.g. mobile devices and the Internet-of-Things) show significant opportunities as facilitators of innovative ways to engage visitors and measure their experience during the visit. New ICT based tools enable new data-driven business models that effectively aid the sustainable revitalization and valorization of Cultural Heritage.

This paper aims at investigating how cultural heritage owners could digitalize the visiting process, measure the engagement of visitors with digital tools and turn data collected during the visits into value for their business model.

*In particular, results achieved by the AMAmI (**A**ncient and **M**odern, **Am**bient **I**ntelligence) Project will be presented: a multi-site real world experimentation of the adoption of digital tools (proximity technologies, mobile, sensors, user-location-based content delivery platforms and big data analytics systems) to deliver an Ambient Intelligence enabled user experience and thus strengthen the management policies of cultural heritage assets.*

Two case studies with different management model and physical environment will be discussed and compared: MAGA Museum of Modern and Contemporary Art sited in Gallarate and Masnago Castle Museum of Modern Art sited in Varese.

Keywords: Cultural heritage management, Cultural asset valorization, Ambient Intelligence, Internet-of-Things

JEL classifications:

O32 – Innovation, Research and Development, Technological Change, Intellectual Property Rights – Management of Technological Innovation and R&D

O33 – Innovation, Research and Development, Technological Change, Intellectual Property Rights – Technological Change: Choices and Consequences, Diffusion Processes

Introduction

In contemporary society, cultural heritage sites, and museums in particular, are assuming a new, more relevant, role: they are not anymore considered as mere space-time delimited containers of pieces of cultural artifacts as they used to be. In the last years, society has changed at a very fast pace, as never before. Nowadays people think of themselves as persons, no more as public; they interact continuously with the environment or with other people by means of their own mobile devices that are always connected through the Internet. Hence, their expectations have increased: museums visitors expect to live an experience that must be interesting, involving, amazing and worth of being shared.

The widespread diffusion, on one side, of powerful smartphones and tablets that enable new interaction modes and that allow mass-level communication, and, on the other side, of devices, such as BLE beacon, able to react automatically to a set of triggering events, may give effective answers to those new needs.

Many museums understood that evolution - some of them have also ridden it - rethinking their own role, redesigning their cultural offering and services, activating new modalities and conduits to relate and interact with their visitors.

Those museums have changed their approach. Their offering of exhibits and services is visitor(-user-client)-centered: visitors are actively involved in different ways; in some cases, they are even encouraged to contribute themselves to the exhibits. In that way, museums have valorized their cultural offering achieving different results: not only they succeeded in improving their visitors' satisfaction, but they were also able to improve their economic sustainability.

Information and Communication Technology has an essential role in this process and accelerated the modernization of museums both toward consolidated technologies such as the Internet and the WWW, and toward more advanced systems and tools, for examples those that take advantage of the BYOD (Bring Your Own Device) approach. In fact, people, and visitors as well, nowadays bring and use their own smartphones and tablets always and everywhere, because they are essential tools for their daily lives (Augusto 2010). This situation implicates advantages, but also risks and needs (Dowden 2007): consciousness about the need of rethinking old practices, new knowledges in order to manage information (Mandelli 2011) and contents (Kuusik 2009) in the right way, active promotion of the new opportunities (Sayre 2015).

Museums are offering new customized modalities of fruition thanks to the Internet. Museums on the Internet (or cyber, virtual, electronic, Internet, online, digital museum) (Svilicic 2010) got rid of borders of space and time, opening to visits from different places and in different time (before and or after the visit *in loco*).

Moreover, Internet and the web evolution opened museums to the social dimension too, allowing them to meet their customers' needs non only in terms of passive spectatorship, but also of joint participation: visitors can collaborate themselves to enrich the offer given by museums. Sometimes those users' contributions helped museums in redesign their offer and sometimes they have become a part of the exposition itself. Some museums where able to improve their communication channels (from free word of mouth up to social media) and to manage them effectively (i.e. by reusing the same contents on different channels with little but appropriate adaptation) thus increasing even the economic return and their fund-raising ability (Lazzaretti 2015).

An additional way of technology-based valorization, gaining more and more approval, is the enhancement of the experiencing component of the visit and of the level of personalization, both from the point of view of contents (richer and richer), and from the point of view of fruition (more and more diversified) thanks to systems and applications of Ambient Intelligence (AmI).

Ambient intelligence usually refers to environments where electronic devices are introduced in order to sense people presence and to appropriately react to such presence. Such devices work in a seamless way to support different tasks in a "natural" way; they use pieces of information distributed in a number of different places and devices (often referred as the Internet-of-Things). As these devices grow smaller, more connected and more integrated into our environment, the technology disappears into our surroundings until only the user interface remains perceivable by users.

The ambient intelligence paradigm builds upon pervasive computing, ubiquitous computing, profiling, context awareness, and human-centric computer interaction design and is characterized by systems and technologies that are embedded, context aware, personalized, adaptive, and anticipatory (Zelkha 1998; Aarts 2001).

In literature, many authors have explored Ambient Intelligence, so we can find many definitions. Among these, we would like to cite the following ones:

- "We refer to the mechanisms that rule the behavior of the environment to provide flexible and intelligent services to users acting in their environments" (Augusto 2010)
- "Ambient intelligence is the vision of a technology that will become invisibly embedded in our natural surroundings, present whenever we need it, enabled by simple and effortless interactions, attuned to all our senses, adaptive to users and context-sensitive, and autonomous. High-quality information access and personalized content must be available to everybody, anywhere, and at any time" (Weber 2005);

Some of them point out how AmI enables adoption of devices that are non-invasive, interconnected, adaptable, dynamic, embedded, smart, and that, with their operations, may help people both in their own activities, and in the interaction between people and the environment. "There are strong reasons to believe that our lives are going to be transformed in the next decades by the introduction of a wide range of devices which will equip many diverse environments with computing power. These computing devices are coordinated by intelligent systems that integrate the resources available to provide an 'intelligent environment'. This confluence of topics has led to the so called area of 'Ambient Intelligence'" (Augusto 2007).

These AmI devices and tools have in fact proved especially effective, without being invasive, in museum environment: on one hand, they can convey information and provide services to museum visitors; on the other hand, they can collect from the field data related to visitors' preferences thus allowing a sort of customization of any visitor's experience. Museums can hence be able to adopt such techniques in order to retain their regular customers and attract new ones.

The AMAmI (Ancient and Modern Ambient Intelligence) project has been developed during the second half of 2015 within this framework: it is an applied research project that proposes a model enabled by technology to effectively enhance institutes and places of culture. Its effectiveness has been tested in two different environments, two different Italian museums, both sited in Lombardy, where new AmI technologies, mostly enabled by digital devices, have been introduced in response to new requirements.

Motivation

The research presented in this paper aims at investigating how cultural heritage owners could digitalize the visiting process, measure the engagement of visitors with digital tools and turn data collected during the visits into value for their business model. The project had two main goals:

1. to identify (and then to apply in real environments) innovative effective and replicable methods to enhance and promote institutions

and places of culture; these methods are based on new technological tools aiming at increasing both the content usability and the customers' experience;

2. to collect information (under the form of big data sets) about visitors' preferences and interests thus allowing better understanding of users' likings to support both strategic and functional organizational decisions; in this way we think we could improve the overall sustainability of the museum (or of the involved place of culture), and hopefully of its reference area.

The proposed method and approach has been also applied in a multi-site real world experimentation: two Italian museum both located in Varese province have been involved in the AMAmI project, namely the Civico Museo d'Arte Moderna e Contemporanea at Castello di Masnago (Varese), and the MA*GA Museum (Museo Arte Gallarate).

Worded in other words, the main research question of the project presented in this paper can be stated as follows: consider the adoption of digital tools such as proximity technologies, mobile, sensor, user-location-based content delivery platforms and big data analytics systems (i.e. the ones implemented at Castello of Masnago and MA*GA). Can it enable a sustainable Ambient Intelligence Model for the valorization and revitalization of (material and immaterial) cultural assets? Can it enhance their horizontal (in terms of public), and vertical (in terms of contents) fruition?

In addition, there are further, more specific, research questions: can those digital tools enhance museums visitors' experience? Moreover, can they provide museums owners with relevant information to better understand their customers and to improve their tactical and organizational choices? Can these tools enhance the economical sustainability not only of a single cultural site but also of the whole cultural system in the surrounding area?

The proposed architecture

System specifications

During the project, we learnt, thanks to the continuous discussion with curators of cultural sites, that the design of an innovative visiting experience should consider cultural objectives that are peculiar for a museum as well as limits and opportunities connected to the application of the state of the art of digital technologies. While other researches focus on technology paradigms such as the Internet-of-Things and Augmented Reality and push their use beyond the possibility to adopt it at a large scale, we decided to define the system specifications considering both sustainability and replicability of the solution for other cultural sites beyond the experimentation.

Thus, we decided to design the system around three ICT artifacts that allowed us to deliver a market ready solution: (1) Bluetooth Low Energy beacons, (2) mobile devices, and (3) cloud infrastructure. We consider such mix of technologies the perfect blend to match the requirements connected to the innovation of museums visiting processes with available and deployable technology. The following paragraphs will present three main pillars that drove the design of the system: (1) devices and the BYOD paradigm, (2) user interaction and information flows (push vs pull) and (3) availability of Internet connectivity inside of the cultural sites.

(1) Devices and the BYOD paradigm

Nowadays BYOD (Bring Your Own Device) paradigm apply also to museum visitors: they usually carry a personal mobile device, such as a smartphone or a tablet, capable of managing multimedia contents and presenting them to the user himself in a natural way. Such paradigm opens new opportunities for museums: the possibility of empowering the visiting process while lowering the cost of the technological infrastructure. For instance, exploiting the presence of visitor's devices to deliver contents about exhibitions or specific works of art, a museum could completely replace audio guides with apps or downloadable digital contents, lowering the acquisition cost and the total cost of ownership (TCO) connected to the proper management of such devices. Visitors, on the other hand, receive trough their smartphones a new kind of museum guide that they can feel as customized and personal, and that is easily accessible thanks to the familiar user interface of their device.

(2) User interaction and information flows (push vs pull)

Museums are already deploying and experimenting guides that are augmented by the availability of additional digital contents that could be retrieved from the web by visitors in a contextual way. In the most common implementation, to retrieve the relevant information, a user has to scan a QR Code (Quick Response Code, a kind of 2D barcode initially developed by DENSO WAVE and now royalty free) or touch a NFC tag (passive Radio Frequency Identification - RFId - tags supported by several Android based smartphones and tablets) placed near a specific work of art with her personal mobile device. In such processes, information flow works with a pull logic: the user initiates the information exchange thus she is aware of the context where works of arts are displayed and she wants to get more information.

We call this kind of ICT artifacts technology-enabled pull touchpoints. Discussing with our partners of AMAmI project we envisioned a strong limit in this approach that is not in the technology side: the user experience during the visit is continuously disrupted whenever the visitor wants to get more information and she must perform a series of activity that are difficult to blend inside of the exhibition itself.

If such logic is deployed, the user has to:

- stop the visiting path inside of a room or a corridor and reach the technology-enabled pull touchpoint that is usually placed near or inside the description plate;
- have previous knowledge about how to use the technology-enabled pull touchpoint and perform the necessary steps to get the information, or
- be informed by the museum staff about the process.

We think that the latter point could be the most problematic for museum willing to deliver a seamless innovative user experience: the user must be engaged enough to decide to follow the process and interact with touchpoints, and reaching such level of engagement could be quite expensive. Moreover, if the result of such interaction is perceived of poor quality for heterogeneous causes, such as smartphone malfunctions or unreadable touchpoints, visitors may be discouraged in reiterating such experience. In such cases, the return on investment of the cultural site is lower: additional curated contents would not be exploited by visitors who may end the visit unsatisfied, knowing that there would have been more information linked to the works of art that was inaccessible.

One of the biggest complications of processes based on technology-enabled pull touchpoint seems to be the absence of control of the curator over every activity that should be performed by visitors, leaving grey areas that undermine the efficiency and the effectiveness of the deployed solution.

We decided to design a system capable of providing the users with an information flow based on a push logic. After a technology-scouting phase, we found that Bluetooth Low Energy Beacon devices, or BLE Beacons, could be used to create efficient technology-enabled push touchpoints. BLE Beacons are battery equipped radio frequency based emitters (a kind of RFId active tags) that continuously send an identification code that could be received and processed by several smartphones and tablets in the market: using this identification code, mobile devices can calculate their position inside the exhibition. If paired with specific mobile applications BLE Beacons enable innovative solutions that makes information accessible by users in a frictionless way: museum guides built with such technologies automatically push contents to visitors’ devices based on their position without requiring user interaction. Visitors are thus engaged with a better user experience as contents are contextually delivered while they enter a room, or walk through a corridor, or stop in front of a specific work of art.

(3) Availability of Internet connectivity inside the cultural sites

We performed several surveys inside the cultural sites involved in the project to check the status of Internet connectivity and its availability to visitors. Both WiFi and 3G/4G connectivity were tested and we found some areas where the performance was suboptimal for the solution we were designing: lack of coverage and slow speed would have resulted in a poor user experience. We discussed our findings with the curators and we learnt that such situation is surprisingly common, especially if the cultural site is an historical building with walls that tend to attenuate WiFi and 3G/4G signal. We had to design a system that automatically sync and caches contents inside of visitors’ devices when Internet connectivity is available in order to make the museum guide reliant to the lack of Internet connectivity.

System deployment

During the specification design phase, we had to select the right BLE device for the system we were deploying. We discussed with curators and the first physical characteristic that we had to consider was the aesthetics of the device itself: as BLE Beacons would have been placed near work of arts, curators favored devices that could perform their function without modifying the exhibitions setting, disrupting with their presence the visitor experience. Following this specification, we had to exclude devices with a gaudy design and to evaluate the possibility to hide BLE Beacons inside mobile walls, furniture, behind or above architectural elements, while preserving their operating performance. We then performed several technological tests in order to identify devices that were suitable for our application. We verified, considering batches of ten beacons from five different vendors, their average reliability in terms of signal strength, polling repeatability, battery duration and configuration capabilities: at the end of the test, we could narrow the number of vendor we were considering. Then, the last selection step was performed inside the museums in order to stress test the devices in a real setting and select the device with the highest performances.

Having selected the BLE Beacon devices, we performed several campaigns of test inside the museums in order to place the hardware and calibrate the interaction between BLE Beacons and the mobile application. We had to define the specific content distribution logic of the system.

At first, we tried to place one beacon for every piece of art, but after some simulations, we found technical limitations and user interaction problems that forced us to define a different setup. While it is technically possible to identify single BLE Beacons even if they are very close, in rooms where works of art are very close to each other signal strength fluctuations caused by environmental noise difficult to predict (i.e. the presence of visitors itself) cause a degradation of the push logic performance that ends in a poor user experience.

We discussed with museums curators and we concluded that, according to the architectonical features of the museums and to the visiting processes that were used, it was not necessary to put a BLE Beacon for each work of art, but we could group contents in thematic rooms or homogeneous areas.

Thus, one BLE Beacon were placed for each thematic area: within this logic, visitors are free to follow the visiting path defined by curators or customize their visits to their needs or passions. Whenever they enter a room or approach a new thematic area, they are promptly notified with relevant and contextual contents through their mobile devices and they can decide to access such contents. The user is always in control of what is happening on her mobile device and can always decide the order of fruition of every work of art (even if curators can always suggest a specific path) and the timings of her stay inside of a thematic area.

This new configuration, one BLE Beacon for multiple work of arts, satisfied the requirements of the system in terms of performance and user experience, and was thus accepted by curators: the two mobile applications that were developed according to the described logic are presented in the following paragraph.

App design

The app design phase has been made simpler and more effective by playing this phase inside the museum itself, inside the same places where the app is supposed to be used.

We decided to design and build the visit by working directly inside the museum and not in a laboratory and that was probably the most effective factor for the project success: in fact, the app has been natively developed to make the most out of the hardware devices and the site-specific properties.

*App MA*GA Smart Guide*

App Musei di Varese

Once started, the app shows three sliding screens that explain the museum context and how to use the app. This structure allows the user's smartphone to load in advance all media content that will be shown during the visit while the user is still reading the introduction.

*MA*GA Smart Guide: screenshots of the starting phase*

Once all the data have been loaded, the app displays a button that prompts the user to start with the interactive visit. From this moment on, when the user moves within the museum, the smartphone will change the information displayed on the screen depending on the position, answering whichever beacon is in the nearby. The average response time (i.e. how long does it takes from the moment a user enter a room and the moment when the phone shows the corresponding information) is between three and four seconds. A faster response is possible, but it would imply a shorter battery life for both the beacons and the smartphones.

The beacons have been programmed to emit a recognition signal on a regular basis approximately every 750 milliseconds. A higher frequency (the maximum is 100 milliseconds) would bring the beacon to be recognized in a shorter time, but the battery would be exhausted in less than 6 months. On the other side, the smartphone searches for new beacons once a second (this frequency can be modified in Android, but not on iOS); hence, any improvement of the beacon frequency appears to be irrelevant with respect to the whole system performance.

Moreover, the app requires that the smartphone recognize a beacon with a high level of confidence, to avoid situations of intermittently switching between different beacon (and hence between different set of information). Hence, the adopted sampling model requires the smartphone to recognize the beacon a given number of times before showing the corresponding information. That is why the response time is between three and four seconds.

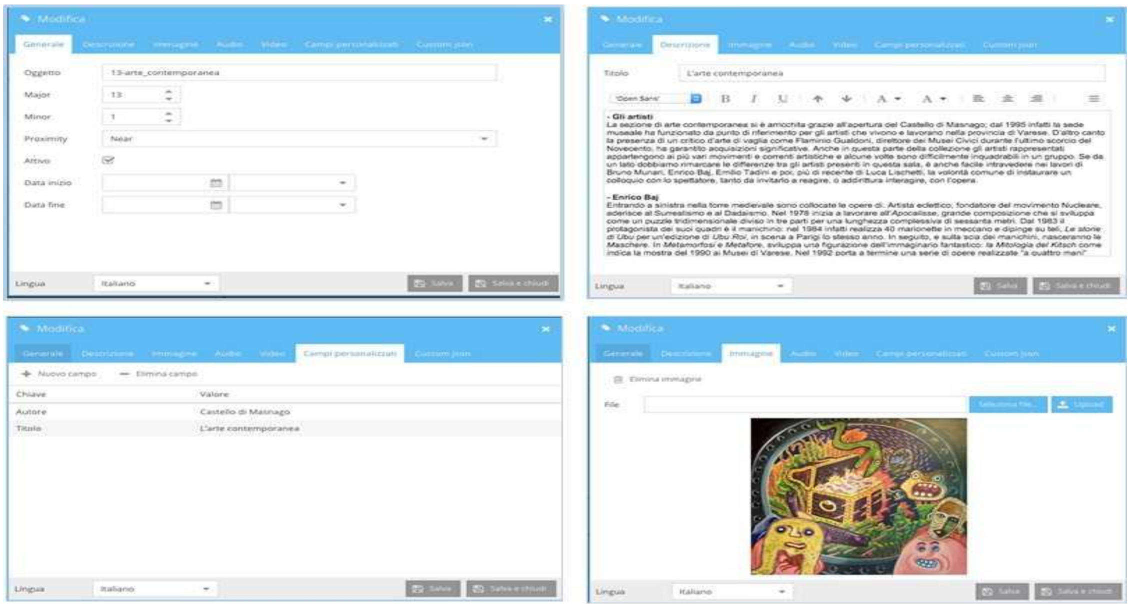
Besides, additional work was required to calibrate the transmitting power of each beacon since their behavior depends on the shape of the room and on their position with respect to the walls. In such cases, it is not possible to standardize the beacon configuration and each device must be individually set up.

App Contents

In order to give complete flexibility to curators and to release a system that could be easily extended in the future to include more work of arts or to support upcoming exhibitions, we decided to decouple app logic and exhibition related contents. We chose to manage contents with a cloud based Content Management System (CMS) specifically developed to handle contents linked to BLE Beacons. The interface of this CMS is so easy that it can be used by people without any technology background: we considered this a key aspect because we wanted to deploy a system that could be managed directly by museum personnel without external help or consultancy.

Moreover, such CMS contains an analytics module that gives the possibility to track the visiting experience by monitoring the interaction of the user with contents and physical spaces, and to present relevant easy-to-read reports that curators could use to improve the guide or the visiting process itself.

We integrated the content delivery logic of this system with the mobile applications using the available CMS Application Programming Interfaces (API).

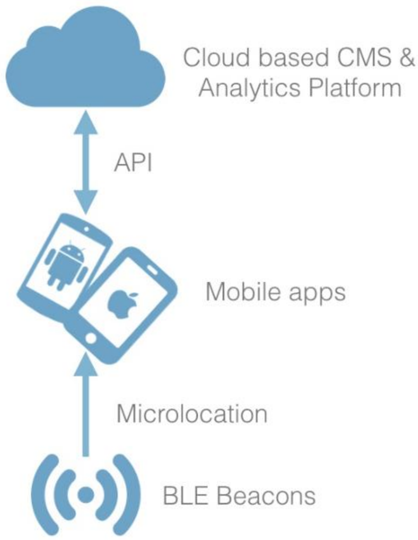


Contents are uploaded and updated by curators using the cloud based CMS

Curators use the cloud based CMS to upload and update multimedia contents (texts, images, audio files and videos) that are automatically synced with the mobile application installed by visitors and seamlessly presented to users during their visit thanks to the BLE Beacon positioning system. In this way, curators can easily redesign the visiting process with original and contextual contents that are blended with the peculiarities of every exhibition, keeping the design of the user experience under their direct control.

This choice completed the design and deployment of the system. As a result, the final ICT architecture of AMAmI project, presented in the schema reported below, is composed by four specific elements:

- BLE Beacons
- Mobile Applications
- Cloud based CMS
- Cloud based Analytics platform



AMAmI project final ICT architecture

The two mobile applications we developed are now available on the Apple App Store and can be downloaded free of charge.

*MA*GA Smart Guide and Musei di Varese are available on the Apple App Store*

Results and conclusions

The AMAmI project can be considered as a project for technology deployment to support operational processes within companies and organizations in general. The entities involved did identify a need (how to improve the museum visit by increasing user engagement and by giving easy access to all information stored in the archives) and an opportunity (use of low-cost technology cost that included, in fact, the devices owned by the visitors themselves).

Based on the context characteristics we decided to adopt an engineering approach, starting from the whole system specification, until the definition of the sets of data to be collected during customers' visits and the identification of all the Key Performance Indicators (KPI) to be monitored in order to evaluate the system performance.

This approach allowed us to achieve a working tool in both the trial places and to observe, even if in a limited life span, some qualitative and quantitative results. We are still monitoring the two implementations and, thanks to the adopted KPI system, we will be able to extract information about the entire cultural asset performance.

We will now present the earliest qualitative and quantitative results. We may be able to conduct a more detailed analysis later on, when the system will be in place since a longer amount of time.

Qualitative results

Qualitative results can be described by considering the following four topics:

(1) the adopted technologies and the corresponding characteristics,

(2) the content features,

(3) the organization structure and the system management,

(4) the communication of the new museum features to museum visitors.

Let’s briefly examine all these four issues.

(1) Adopted technologies.
The adopted HW have proved particularly suited to the context: the chosen devices are cheap, simple to use even by non-technical personnel and easily reconfigurable to adapt to different installations, a very important aspect for museums displaying temporary exhibitions.

To simplify maintenance and to minimize the intervention of outside staff, we choose to use beacons equipped with standard AAA batteries (since anybody can easily replace them) instead of beacons equipped with non-standard or sealed batteries. This choice showed to be very effective since it allowed us configure the system in a quick and easy way as often as it was required by changes in the exposition structure.

(2) Content features.
The adopted combination of tools (namely museum’s beacons and visitors’ smartphones) enables two very important outcomes: the possibility to present to the customer any piece of information at the right time and in the right place and the ability to leverage users’ personal devices.
A set of tests performed on the field did show that when information flows through users devices (smartphones and tablets) such information flow must
(a) adapt itself to the device characteristics,
(b) be presented following a “push” approach (i.e. the information is supposed to be presented where and when it may be useful, without waiting for any request issued by the user, but without disturbing the visitor)
(c) take advantage of the new technologies capabilities (e.g. interaction) that were not exploitable with previous technologies.

Because of these reasons, we decided to design new information flows and, hence, to generate new contents more suited to the characteristics of the new visit process/experience. Even if this decision resulted in increased costs, we thinks it will be rewarded by better alignment between the adopted technology and the visitors’ experience.

(3) Organization structure and system management.
The adoption of new processes and new technologies often requires the re-definition of the organization structures. It may be useful or even necessary to introduce specific responsibilities, dedicated to the continuous management of the new processes and to maintain these processes efficiency over time.
Even if the adopted technologies, once implemented, require few

maintenance, in order to give continuity to the project both cultural sites involved in the AMAmI project are undertaking the required organization modification either by introducing new internal roles and tasks or by entrusting these task to a third party.

(4) Communication of the new museum features to customers.
New visitor/museum interaction models were defined by considering a user-centric approach, but the success of the current implementation will only be ascertained by assessing the performance in relation to the effective use by museums visitors. It is therefore of great importance to inform and educate visitors to new possibilities offered by the new tools and new devices.

While recognizing the need for communication activities of this type, it was not yet possible to define the ways in which these campaigns may be implemented. It is a point that will likely be addressed differently by the two museums: they will have to figure out how to integrate this activity with their regular processes of interaction with their respective end users.

Quantitative results

Projects results achieved in both test sites are being evaluated by observing a number of different KPIs pertaining to both the implementation characteristics (type 1 KPIs) and the visitors' technology supported experience (type 2 KPIs).

In the first group, we considered KPIs useful for assessing the degree of adoption of the system by the two organizations:

- Installed devices (beacons) in the museum;
- New "contents" produced (text, images, audio, video, …);
- Number of exhibitions in which the system has been used.

Results achieve so far (up to December 2015) are reported in table 1.

Table 1. Quantitative results: type 1 KPIs

Type 1 KPIs	MA*GA Museum	Castello di Masnago
Installed beacons	15	13
New "contents"	72	16
Exhibitions	3 (temporary exhibitions)	1 (permanent collection)

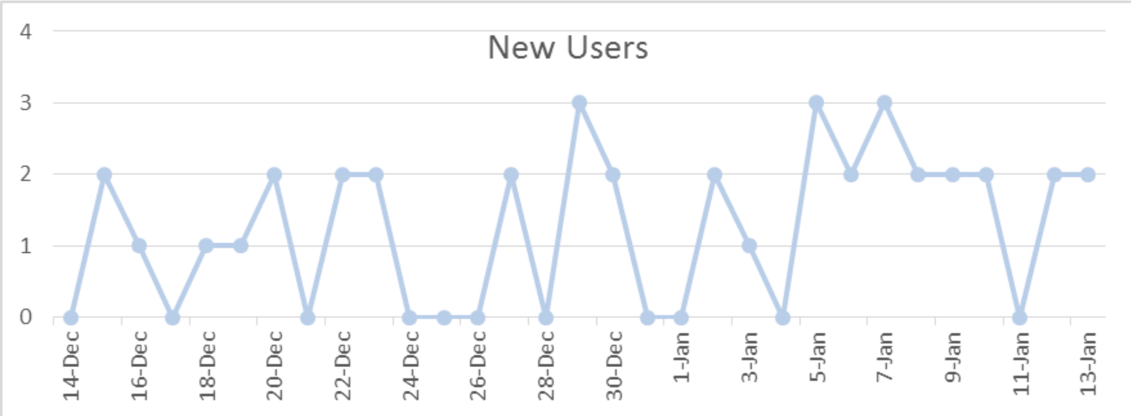
MA*GA Museum shows a more effective use of the technology mainly because of the higher number of activities scheduled during test time span (e.g. a number of different exhibitions were scheduled at MA*GA during these months).

A second group of KPIs (referred as type 2 KPIs) has been defined and it is supposed to be monitored by museum personnel. These KPIs focus on the visitor experience and they have been defined as follows:

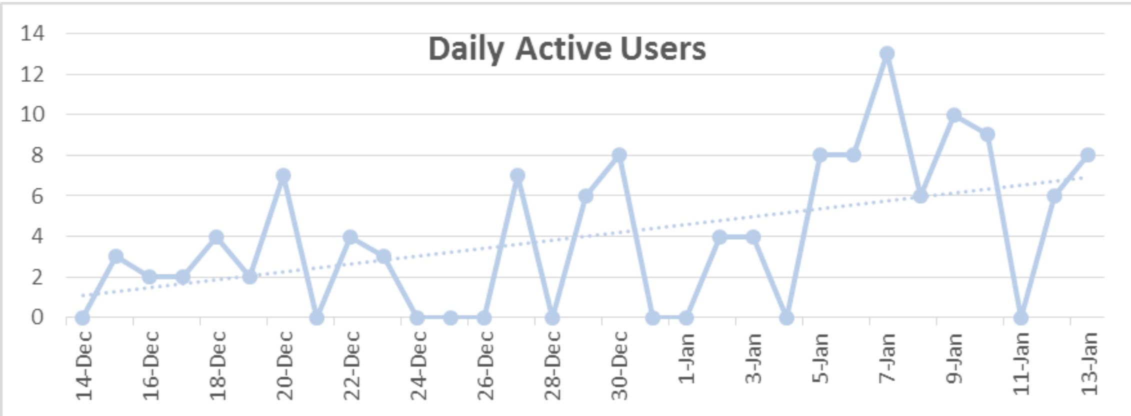
- number of visitors who have used the application;
- number of visitors who use the application per day;
- number of visitors who use the application per month;
- number of visitors who use the application in two days;
- new users per period;
- total number of sessions per period;
- the most visited museum places for the period;
- the most observed works for the period;

- the most viewed contents for the period.

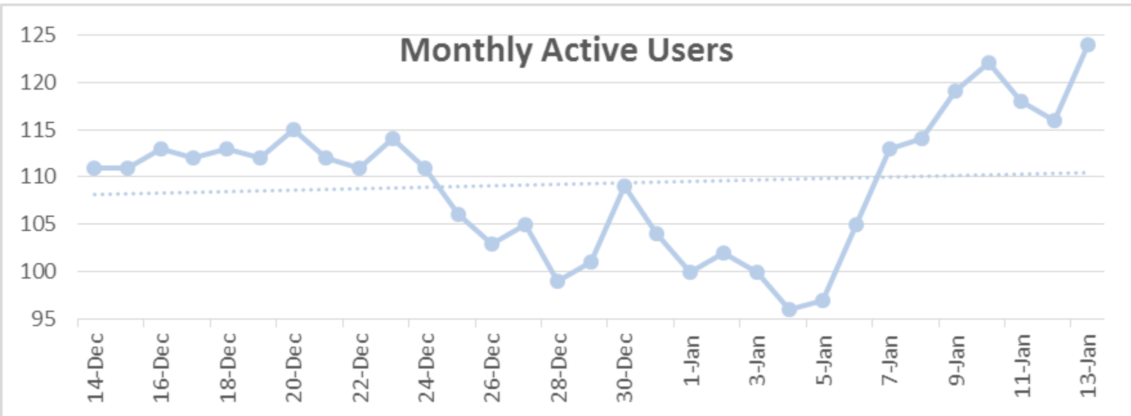
Due to the short observation time (the system has been available since December 2015) we did not yet achieve significant results related to type 2 KPIs. Nonetheless, example charts 1 to 4 shows how these KPIs will be presented to museums staff in order to monitor the evolution of the system use.



Example Chart 1 – New Users [30 days]

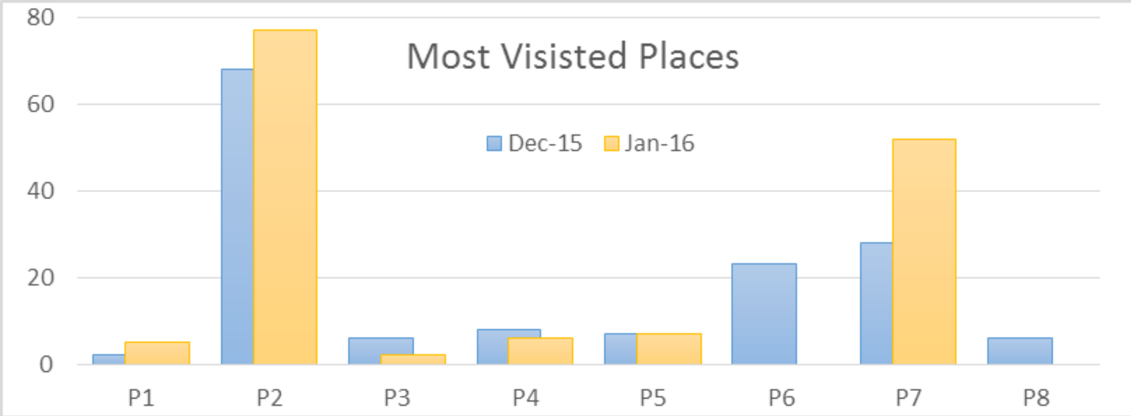


Example Chart 2 – Daily Active Users [30 days]



Example Chart 3 – Monthly Active Users [30 days]

The continuous KPIs monitoring will allow understanding of how the new option are perceived and adopted by museum visitors and hence it will help to design the whole system possible evolution. It can also be used to define operational objectives to be declined on the organization to promote the use of new tools.



Example Chart 4 – Most Visited Places [two months]

The systematic monitoring of type 2 KPIs is starting in these months. These KPIs are perhaps the most interesting ones because they allow understanding of the visitors' behavior: which routes do they choose, which points do they like …. Hence, museum staff can use these data to understand users' expectations and to add additional services or to adapt exhibition layout to fulfill these expectations, possibly amending both the multimedia content and the physical installations.

Further research is under development to analyze these results and to find if these museums are actually succeeding in improving their effectiveness by using the solution presented in this paper.

References

E. Aarts, R. Harwig, M. Schuurmans, "Ambient Intelligence" in The Invisible Future: The Seamless Integration Of Technology Into Everyday Life, McGraw-Hill Companies, 2007.

S. Alletto et al., "An Indoor Location-Aware System for an IoT-Based Smart Museum," in IEEE Internet of Things Journal, vol. 3, no. 2, pp. 244-253, April 2016.

M. Angelaccio, A. Basili, B. Buttarazzi and W. Liguori, "Smart and Mobile Access to Cultural Heritage Resources: A Case Study on Ancient Italian Renaissance Villas," Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), 2012 IEEE 21st International Workshop on, Toulouse, 2012, pp. 310-314.

J.C. Augusto, "Ambient Intelligence: The confluence of ubiquitous/pervasive computing and artificial intelligence", in J. A. Schuster, Intelligent Computing Everywhere, Springer London, 2007

J.C. Augusto, H. Nakashima, H. Aghajan, "Ambient Intelligence and Smart Environments: A State of the Art", Springer, 2010 [http://link.springer.com/book/10.1007%2F978-0-387-93808-0].

E. Bonacini, I musei e le nuove frontiere dei social networks: da Facebook a Foursquare e Gowalla, OPenarchive, 2010 [http://openarchive.icomos.org/1082/1/Bonacini_2010.pdf]

D.J. Cook, J.C. Augusto, V.R. Jakkula, Ambient intelligence: Technologies, applications, and opportunities, Pervasive and Mobile Computing, Volume 5, Issue 4, August 2009, Pages 277-298, ISSN 1574-1192, http://dx.doi.org/10.1016/j.pmcj.2009.04.001. [http://www.sciencedirect.com/science/article/pii/S157411920900025X]

S. Costantini, L. Mostarda, A. Tocchio, P. Tsintza, "DALICA: Agent-Based Ambient Intelligence for Cultural-Heritage Scenarios", IEEE Intelligent Systems, vol.23, no. 2, pp. 34-41, March/April 2008, doi:10.1109/MIS.2008.24

V. Doljenkova, Beacons: Exploring Location-Based Technology in Museums, March 30, 2015, http://www.metmuseum.org/blogs/digital-underground/2015/beacons

R. Dowden, S. Sayre, "The whole world in their hands: The promise and peril of visitor-provided mobile devices", in H. Din, P. Hecht (eds.), The digital museum: A think guide, p. 35-44, American Association of Museums, 2007

Fondazione Fizcarraldo, Il Museo e la Rete: nuovi modi di comunicare. Linee guida per una comunicazione innovativa per i musei, 2014, disponibile online: http://www.fizz.it/home/sites/default/files/allegati/articoli/pdf_articoli_completi/museorete_lineeguida_ricerca.pdf

A. Kuusik, S. Roche, and F. Weis "Smartmuseum: Cultural content recommendation system for mobile users", in Proc. Fourth Int. conference on Computer Sciences and Convergence Information Technology, Tallinn, Estonia, 2009, pp. 477 – 482.

L. Lazzeretti, A. Sartori, N. Innocenti, "Museums and social media: the case of the Museum of Natural History of Florence", International Review on Public and Nonprofit Marketing, 2015, vol 12, n 3, p 267-283

E. Mandelli, A. Resmini, L. Rosati, Architettura dell'informazione e design museale. Tafterjournal, 37, p 7, 2011, http://www.tafterjournal.it/2011/07/01/architettura-dell%E2%80%99informazione-e-design-museale/

N. Mallik, "Museums 2.0: When Art meets (iBeacon) Tech", Museums, 6 Feb 2015, https://www.linkedin.com/pulse/museums-20-when-art-meets-ibeacon-tech-neha-mallik

F. Sadri, "Ambient intelligence: A survey", ACM Comput. Surv. 43, 4, Article 36, Oct 2011, DOI=http://dx.doi.org/10.1145/1978802.1978815

S. Sayre, Bring it on: Ensuring the success of BYOD programming in the museum environment, The annual conference of Museums and the Web, 8-11 Apr 2015, Chicago, IL, USA, http://mw2015.museumsandtheweb.com/paper/bring-it-on-ensuring-the-success-of-byod-programming-in-the-museum-environment.

T. Scartabelli, Media e didattica museale. Nuove tecnologie per educare: quando la multimedialità e interattività incontrano il museo e il patrimonio culturale, Lulu.com, 2014.

N. Svilicic, Creation and Typology Definition of the Museum on the Internet, Coll. Antropol. 34, 2, 587–594, p. 590, 2010.

W. Weber, J. Rabaey, E.H.L. Aarts (eds.), Ambient Intelligence, Springer, Berlin, 2005

E. Zelkha, B. Epstein, S. Birrell, C. Dodsworth, "From Devices to "Ambient Intelligence"", Digital Living Room Conference (June 1998)