Exploitation of Mobile Access to Context-Based Information in Cultural Heritage Fruition

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***Abstract*—More than one billion smartphone users are estimated by 2014. With this in mind, visiting cultural heritage sites and exhibits may offer new level of engagement and entertainment just reaching down in our pockets. With orders of magnitude more computational horsepower than a five years-old desktop machine, stuffed with all sorts of sensors, these modern gizmos have a largely untapped potential to gain us access to personalized and on-demand information wherever it is needed. This paper is exactly about this, exploring with several case studies how these devices may become part of a memorable experience during a visit that one may want to share with friends and relatives. Specifically, the paper will focus on the definition of the user-experience (UX), on integration issues, and on context detection within augmented environments in cultural heritage sites, along with a discussion on the lessons learnt.**

Mobile access; context based information; cultural heritage fruition.

I. INTRODUCTION

In recent years there has been an increasing use of personal mobile devices (smartphones, PDAs, tablets), so that they are widely available among people of all ages. They are almost in everyone's pocket and can be used almost anywhere. This wide acceptance is due to the even more intuitive interaction interfaces (touch screens, graphical user interfaces), as well as the different available wireless technologies, both for short and long distance communications (RFID, Bluetooth, WiFi, ZigBee, UMTS, HSDPA, and the like). Such diffusion is also driven by the introduction of various types of sensors and multi-programmed operating systems, that actually creates a positive trend (more than one billion smartphone users are estimated by 2014 – Gartner's studies). This justifies the common interest in the study of new ways of service provision (and brand-new services too) according to the features and capabilities of mobile devices [1] [2].

Thanks to all these features, users are allowed to install all the applications they consider interesting or useful, thus making personal devices an indispensable companion for either business or leisure tasks.

This opportunity has paved new ways to new business models for all those entities, ranging from single individual programmers to large well-organized software houses, working on developing applications for these devices.

The great connectivity, the easiness of interaction and the possibility to be programmed to perform many different tasks, give personal mobile devices a chance to widely become "intelligent terminals" to access any information system appropriately designed in a personalized and context-dependent way.

For all these reasons, one of the most popular uses of such devices is the access to personalized and on-demand information wherever it is needed.

Personal mobile devices are thus successfully exploited for human-environment interaction purposes within pervasive systems. In fact, it has to be considered that such interaction should not be the same for all, since differences in needs and skills of people have to be taken into account to avoid heavy compromises, which could not satisfy anyone. Due to their programmability and wide popularity, mobile devices can be made suitable to operate as remote controllers, or personal adaptive I/O interfaces, for applications remotely running. Needed services can therefore be accessed by means of a well-known device, with no need to learn how to use new kind of interface [3].

There is a large variety of application fields where services can be pervasively accessed by mobile devices, such as context-aware information provision within university campuses [4], augmented reality objects assembly in mobility [5], healthcare systems [6] [7] [8].

One of the fields in which mobile access to information and services is widely exploited is the provision of interactive user profile-based guides in cultural heritage sites. In such field there are several works, focused both on the research and on the application point of view, aimed at the definition of systems or even parts of them (indoor and outdoor positioning, human-environment interaction, user profiling, information retrieval, intelligent behavior, etc.) [9] [10] [11] [11] [12] [13] [14] [15][16][17].

Cultural heritage applications pose several challenges to designers under different aspects. First, because of the large variety of visitors they have to deal with, each with specific needs and expectations about the visit. Second, no two sites are the same, and probably you need a brand new installation for each site, given its characteristics (indoor versus outdoor, distributed versus centralized, individual centered versus group centered, etc.). Lastly, the technologies involved must be robust to failures, redundant and, above all, easy and intuitive to use.

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In this paper we will give an overview of the current state of the art in the field of mobile applications for cultural heritage fruition, to sketch the main issues researchers and developers have to deal with. In particular, we will focus on the definition of the User Experience (UX), on integration issues and on context detection within augmented environments. Then we will shortly present some of our previous works in the field, to introduce the final discussion on the lessons learnt.

II. OVERVIEW

Cultural heritage is a wide concept including tangible goods (monuments, architecture, museums, exhibits) and intangible heritage like languages, folklore, music, dances, festivities, life styles or food habits. As an example the UNESCO in 2010 inscribed the Mediterranean diet on the Representative List of the Intangible Cultural Heritage of Humanity [18].

The definition of a high level User Experience (UX) for cultural heritage fruition of contents is a complex problem with many facets. To provide engaging and exciting UX to the users the main aspects that have to be taken into account are related to the following simple questions:

- Where is the user located or how is it possible to track her/his route?
- Which are the more appropriate contents to provide her/him?
- What are the possible interactions between users and infrastructure?
- How does the presentation of contents affect the user experience?

Some of the issues above are strictly related to technologies and their improvements such as tracking and localization both indoor or outdoor while other are related to psychological or sociological aspects of interaction. Usually the definition of information in cultural heritage fruition starts from the definition of a possible path inside the site, which is the display organization inside an exhibit, or a proper path for an outdoor location. This path organization is usually the "*fil rouge*" of the fruition and the contents reflect this organization. This pre-ordered fruition of contents has two major drawbacks: the users could be not involved in the narrative and the level of deepening could not be appropriate for the user. Some works try to address the presented issues as a whole while others try to solve specific problems.

In the first category some important frameworks has been proposed and financed at European level to support the development of cultural heritage. One of the first projects was AGAMENNON [19]. The project was indented to organize historical and cultural information about archaeological sites in an intuitive and innovative way, using third-generation mobile phones, to provide the users with a guide presenting to them their preferred topics respecting the time scheduled for the visit. Another relevant example is the ISAAC [20] project, which is related to harmonization of cultural heritage contents using semantic web technologies. Another important aspect is the preservation of cultural heritage: the Mosaica [21] project uses web 2.0 and semantic web technologies to achieve such result. Lastly, resorting to Augmented Reality [22] [23] allows to reach a deeper level of user's engagement.

Context awareness plays as well an important role in designing mobile applications, especially when focused on cultural heritage related projects. A good definition of *context* is given in [24]:

> "*any information that can be used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves".*

This conceptual definition includes all the aspects related to context but from an operative point of view is important to define what are the sources of information in the environment (e.g. sensors, people, points of interest, objects) and how is organized the computational model and the architecture of the overall system. Starting from the sensors, mobile access can be advantaged from the new categories of sensors like GPS (Global Positioning System). A recent Gartner's research has estimated in 526 million worldwide the number of users owning devices equipped with location based systems (LBS), significantly increased from the 100 million in 2009.

Location based systems are essentially outdoor and indoor. Outdoor LBS are mostly based on GPS (Global Positioning System) satellite infrastructure. The level of accuracy available is in the order of a few meters and it is generally adequate for location based information providing. Indoor positioning suffers of the degrading reception of GPS-based systems. Rather than relying on position accuracy it is often more important to offer capabilities such as recognizing boundaries and positioning a person using symbolic locations (e.g. "in the hall" or in "near the building").

A number of methods have been proposed in recent literature to design indoor LBS using different class of sensors like infrared beacons [25][26], radio signals from wireless LAN [27], [28], RFID technology [29] or cameras and microphones [30] to detect user location, or combinations of them. An alternative to employing dedicated infrastructure embedded into the environment is to use passive approach. In this case, users are not continuously tracked but information about their position can be discretely provided on demand using a fiduciary markers. Following this idea, in [31] a system used as a location-based conference guide is presented. The system can be used in large-scale events with no further costs due to other equipment. Another way to achieve the same functionality is through the detection of the position by comparing a set of floorplans and an image taken from the cell-phone camera [32]. This method has a major disadvantage because it requires *a priori* processing of all the floorplans for a particular building.

Besides user's location, additional challenges in the design of information systems for cultural heritage are related to contents organization and the growing importance of the social dimension of their use. The first aspect has been

addressed in many works. An early work is the definition of a set of different prototypes both for indoor and outdoor guides called Cyberguide [33]. Other relevant systems are the Hippie/HIPS project [34] that is focused on development of an exhibition guide. The possibility to automatically define related information for a guide has been exploited in many projects such as the PEACH project [35] where the generation of some position related contents and post-visit reports are automatically performed. The CHIP project [36] tries to combine Semantic Web techniques to provide personalized access to digital museum collections both online and in the physical museum.

Another point of view to build a museum guide is to target not just a single user but also a group visiting a museum. The Sotto voce [37] system is designed specifically with this goal providing a communication mechanism to support interaction. The next step is the definition of more complex interactions between devices to perform socially aware computing [3] tasks. The ultimate goal is to enable high level Human-to-human interaction [38] which is a challenging new domain where networked information systems and intelligent environments surrounding people converge for the purpose of better satisfaction of users' requirements and anticipation of their needs.

III. THE MAIN CHALLENGES

The challenges in the developing of systems aiding contents fruition in cultural heritage relate to three aspects: definition of the user experience, selection and provisioning of contents, and user localization and routing. These three aspects are clearly strictly related, while the second and the third are functional to the first. In general, one would like to build systems that can increase the value of cultural assets by:

- adding useful information
- avoiding frustration
- amusing and engaging users
- encouraging on-site visit

A. User Experience Definition

The definition of the user experience is a problem that is strictly related to the user's positive sensation and engagement in the fruition of a system designed to give and spread information and contents. As stated, UX is more a qualitative and comprehensive aggregate of single and measurable factors like usability, responsiveness and easiness of usage. A peculiar aspect of the mobile access in term of user experience is the relatively small dimension of screens in portable devices. In order to have a good user experience the user interaction has to be arranged to minimize the number of interactions to accomplish a task or to reach contents. The definition of new gesture-based interface is a natural solution to this problem. We have used gesture-based interface to provide rich multimedia contents for users. The possibility to access immediately information with augmented reality or virtual reality has proven to be effective and natural for users. Another important aspect is to resort to analogies with real objects to give users hints and guidance.

B. Integration and fruition of information

The integration and fruition of information is a challenging problem. For cultural heritage contents are usually of different nature: texts, images, multimedia and structured information. The process of content aggregation is performed as a key component of the user experience design and has to be tailored with attention. One of the main aspects is related to the amount of information provided and to the connectivity for users. Last generation smartphones and mobile devices have increased their connectivity. In this way some contents can be provided ad-hoc and only after an explicit request of the user. The general organization of contents in our experience is to define a narrative path with some degree of freedom for user that feels the information as specifically arranged for them. Another important aspect is the ability to provide direct access to relevant information with shortcuts resorting to virtual reality. This feature is particular important for cultural heritage where the amount of information could be misleading for users requiring only generic information.

C. User and POIs localization and tracking of POIs

To perform user and POIs localization we have used different technologies: GPS, Bluetooth, but also passive markers like QR codes. The possibility to mix these sources of information is essential to build robust systems able to give precise localization both indoor and outdoor. An important aspect that has to be stressed is the necessity to build inexpensive and unobtrusive infrastructures. The purpose is twofold: to maintain the deploy costs as low as possible and to use only the capabilities that are built in in the users' devices. Due to this consideration we are not resorting to RFID technologies as they are not built in in many commercial devices and require additional hardware infrastructure to gain significant advantage using them.

IV. PRESENTATION OF CASE STUDIES

Here we present several mobile apps where context-based technologies are used to reach different goals in user experience. All the apps we present in this work follow the well-known Model-View-Controller design pattern as displayed in Figure 1.

Every time we are going to add a location-based service to an existing app we execute the following procedure. First we create a *Sensor Controller* that is responsible for gathering data from the sensor and store them in the *Context Model*. Exploiting new data stored in the Context Model, along with existing data from an application specific database, a new context-aware technology is added to the app. The goal is reached by designing a specific *View*, i.e. the graphical user interface with which the user interact, and the corresponding *View Controller*, that manages the whole logic and the interaction events related with the new technology added.

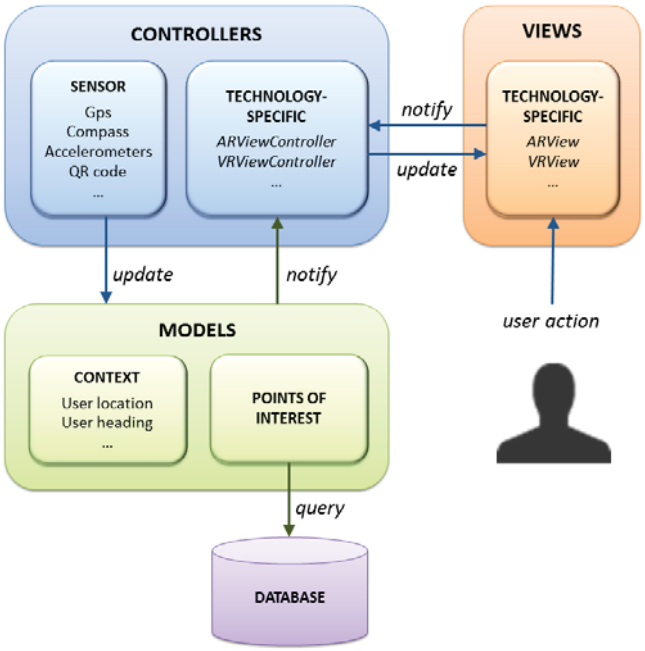

Figure 1. System architecture

A. *Gps, compass and accelerometers*

Streating is the mobile guide for Palermo enogastronomy we have developed.

The app helps to discover Palermo's world of street food, a unique centuries-old culture that need to be explored to actually enjoy the city. Streating takes advantage of data gathered from GPS, compass and accelerometers to build an *Augmented Reality* view (see Fig. 2) that shows the points of interest around the user. The combination of this information gives users the possibility to route their path in the city just pointing the device in a particular direction. In this way they can have information about the nearest place to find a particular kind of food. Users can also have a categorized vision of the possible places according to four food categories. Users can interact with this augmented reality view simply enabling the augmented reality browser with a touch of the interface. For users that are not used to this type of information browsing, it is possible to use a complementary graphic interface showing the information in a more usual way.

Figure 2. Streating AR View

B. *Compass and accelerometers*

When the site is indoor, the GPS is not useful and local embedded sensors, such as compass and accelerometers, can only give the context information needed to enrich the visit.

We managed this situation in the app iPalatina, the guide to the Palatine Chapel in Palermo. The Palatine Chapel is the best example in the world of the so-called Arab-Norman-Byzantine style. It is filled with mosaics of great elegance as concerns elongated proportions and streaming draperies of figures. In iPalatina the users can take an audio tour of the Chapel, following the sequence of steps provided by the app. Furthermore they can enjoy the *Virtual Reality* tour, in which they can navigate a panoramic view of the chapel, centered at the heart of the main nave. The panoramic view is annotated with buttons that play spoken description of the points of interest next to the corresponding button. Users can automatically align the point-of-view of the panoramic view with their own point-of-view simply tapping on the compass button. The alignment is calculated using data from compass and accelerometers. With this technology the users can easily find the information associated with the particular detail they are watching.

In such a situation, Virtual Reality has some advantages over Augmented Reality. The first is that the users can take a tour of the Chapel, before actually entering in the Chapel. In this way they can be encouraged to visit the Chapel. The second advantage is that even while they are on site, they can enjoy some details that cannot be observed with the naked eye. A typical example is the ceiling of the chapel, which is 14 meters (42 feet) high above the floor.

Figure 3. The iPalatina tour

Virtual reality can also be used for outdoor guides, so we used the same functionalities in the iMussomeli app. It enables users to visit and learn stories about the Manfredi's castle in Mussomeli (Sicily, Italy), also known as the

"eagle's nest" for its particular location. In this app users are able to visit the castle with the support of our guide. The chosen POIs are organized in a path with three main groups according to the place layout (see fig. 4). A first group is related to outdoor POIs, the second to the main corpus of the castle also known as the "noble floor", and the third to the subterranean. The guide has also a specific section for the castle's legends that are professionally narrated. The guide is used to support a business model where users can rent on site dedicated devices with the installed guide, or alternatively download their own guide on a personal device.

Figure 4: The iMussomeli tour

C. QR Code

When the points of interest are within an indoor site, one of the most cost-effective and powerful technologies to detect the user's context and to infer user interests is the QR Code.

The developed application named MDMartidec presents the exhibition known as "Sicilia ritrovata. Arti decorative dai Musei Vaticani e dalla Santa Casa di Loreto". The app is a support to discover the pieces in the exhibit, which are mostly unique productions of the Sicilian school from 1530 to 1670.

The main aspect of this app is the fact that it focuses on the detailed description of a small set of exhibits. For each exhibit the app shows some annotated high resolution images. The annotation's goal is to give relevant information about the neighboring details. As users use the app, they navigate through the annotated details by means of animations zooming a detail of the object. At the end of every animation an audio recording of the corresponding annotation is played (see Fig. 5).

Figure 5. MDMartidec

MDMartidec uses *QR Code* for fast selection of the content of interest. If users want to take a random tour of the exhibit, they are not requested to go back to main screen and select the exhibit of interest every time. In this way we have reduced the needed interaction to reach a point of interest.

V. CONCLUSIVE REMARKS

One of the lessons we learnt during our past activity, carried out by our research group within the University and the R&D staff of our university spin-off company [39], is that the main focus must always be on the actual goal the deployed system is aimed at, according to the supposed users, forgetting all the astonishing media (if useless, of course).

In some of our previous works, we have been involved in the implementation of information provisioning systems for large fairs [40]. Such systems are similar to those aimed at the cultural heritage sites fruition, except for the contents, of course: same features, same users behavior, same issues. So it makes sense for us to take into account results and feedbacks even from that experience, in the development of solutions in the cultural heritage field.

Upon the request of the site manager, we proposed a solution to provide people with multimodal access to the available services: a traditional point-and-click interface shown on a touch screen placed on the top of a totem-style case; a personal interface made available through an app to be installed on people's own smartphones; a short range, self-positioning framework based on QR codes to quickly access information related to people's current position.

We tracked both the system usage and the people behavior while searching for information, and we observed that the traditional point-and-click interaction mode was largely the most used one, with a ratio of 100:1 over the personal interface (see [40] for more detailed reports for the 2011 deployment – results of 2012 edition are not yet published, but the ratio raised to 1,000:1). This was mainly due to the main goal of the system, set up according to the visitors needs: to quickly find the preferred item or producer, and locate it on the map with respect to their own position.

In this case, despite the mobile access could have given users more features, both for utility and leisure, users have

preferred to search for the needed information in the fastest way they can. To exploit the mobile access, users had to register to the wireless network, then download the app, and finally use it. Users considered this process too long and not effective, probably due to the mean age of the users and to their actual needs.

As a consequence of this analysis, we are reconsidering the opportunity to include a gesture-based interface we were designing in possible future deployments of the system in similar contexts. The expected results in terms of useful improvement could not be worth the needed efforts in terms of research and development, both in the Human-Environment Interaction and hardware/software fields.

The above analysis can be applied to similar circumstances, so we can summarize the features of such situation as follows:

- Indoor site, with a large number of points of interest;
- No audio/video information available for each POI, only short text and some picture;
- No need of personalized information provision;
- Goal of the system: to search for a POI and to locate it, with respect with the current user's position;
- Users mean profile: mean-aged, both sexes, no particular skills, both business or leisure purposes.

On the other hand, due to the business model we agreed with the Municipality of Mussomeli, we also tracked the behavior of visitors at the Mussomeli's Castle while using our iMussomeli guide.

In this case, the personalization of information provision and the personalized access by mobile devices was highly desirable if not mandatory, due to the contents type and to the site layout. In fact, due to the size of the site and its architecture, visitors have to walk all the time through large rooms and long paths during their visit. The absence of specific stop-spots in this layout makes it not suitable for the deployment of fixed kiosks, so that a mobile device is the best way to describe the site to the visitor.

From the contents point of view, the level of details, the presentation media, and the contents composition should be made according to the users profile (skills, age, expectations and goals). In such situations, the use of different interaction modes (such as voice or gestures) is quite obvious, as well as the use of mobile devices as terminals for personalized interaction media.

During our observations and surveys, we noticed that people really appreciated the possibility to listen to narrations, while seeing correlated pictures and videos right on the spot, using mobile devices provided.

Concluding, the features of such sites, in which the mobile access can be suitably exploited, can be summarized as follows:

- Large sites, mostly outdoors, with a small number of specific POIs;
- The POIs are different, and they have different fields and details to be presented;
- There are multimedia information available for the POIs for the whole site;
- The personalization of information presentation is highly desirable (according to the user's age, skills, and expectations);
- Main goal of the system: to guide people during their visit on the site, or to allow people to know about it even if not on site;

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