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ENHANCING THE TOURISM EXPERIENCE THROUGH MOBILE AUGMENTED REALITY: CHALLENGES AND PROSPECTS

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ABSTRACT

The paper discusses the use of Augmented Reality (AR) applications for the needs of tourism. It describes the technology's evolution from pilot applications into commercial mobile applications. We address the technical aspects of mobile AR applications development, emphasizing on the technologies that render the delivery of augmented reality content possible and experientially superior. We examine the state of the art, providing an analysis concerning the development and the objectives of each application. Acknowledging the various technological limitations hindering AR's substantial end-user adoption, the paper proposes a model for developing AR mobile applications for the field of tourism, aiming to release AR's full potential within the field.

Key Words: augmented reality, mobile applications, tourist experience, experience quality, location awareness

INTRODUCTION

Even though Augmented Reality (AR) as a concept exists since the '60s, it is only since the past two decades that technological advances made possible the formulation of a distinct research field. AR is a visualization technique that superimposes computer-generated data, such as text, video, graphics, GPS data and other multimedia formats, on top of the real-world view, as captured from the camera of a computer, a mobile phone or other devices. In other words, AR can augment one's view and transform it with the help of a computer or a mobile device, and thus enhance the user's perception of reality and of the surrounding environment (Osterlund & Lawrence, 2012). In addition, within an AR-enhanced context, information becomes interactive and easily manipulated in a digital manner.

AR technology is currently used in a number fields, such as medicine, education and simulated training among others (Yu, Jin, Luo, Lai, & Huang, 2010). It is also used within the tourism sector, aiming to improve the tourist experience On the one hand, several examples have shown that AR can aid tourist organizations and professionals towards reaching a wider audience by serving as the delivery technology of appealing multimedia content and mobile applications, fine-tuned to various knowledge levels. On the other hand, AR information systems can help tourists in accessing valuable information and improving their knowledge regarding a touristic attraction or a destination, while enhancing the tourist experience and offering increased levels of entertainment throughout the process (Fritz, Susperregui, & Linaza, 2005). Most importantly, such information systems are able to personalize the delivery of the multimedia content according to the user's characteristics and the use context, thus supporting their deployment for a number of scenarios.

The present paper offers an overview of the use of AR mobile applications, tailored specifically for the needs of tourists and tourism professionals. In the following sections we discuss in detail the current state of the art of information systems and mobile applications that use AR for tourism purposes, in order to highlight the benefits offered to tourists. Finally, the paper proposes an archetypal framework for the development of mobile AR applications for the field of tourism, aiming to release the technology's full potential within the particular field.

TECHNOLOGICAL REQUIREMENTS

Until recently, Virtual Reality (VR) was the most popular technology offering users an interactive, simulated environment. Its main disadvantage, however, is that it prohibits the user from developing a relationship with the real world and the surroundings as it demands one's full immersion within the simulated environment. In contrast, AR allows this communication since one of its prerequisites is the superimposition of computer-generated data onto the real view. This is perhaps one of the main factors for AR's increasing popularity among individual users (Fritz, et al., 2005).

As mentioned, AR applications superimpose 3D and/or 2D graphics on top of the real worldview. This suggests that the available information can be continuously updated through the design of new objects. In turn, these objects and 2D graphics are inserted and handled by the AR applications with the help of geo-location data, or more recently AR tags, which can be easily read by mobile devices and computers. In actuality however, the specific technological requirements for AR mobile applications depend largely on each individual case. All AR mobile platforms require the use of web servers for the hosting of data, databases and AR tags for points of interests (POIs) in the case of tag recognition. In addition, such applications require that users are equipped with smartphone devices. Moreover, in cases of location-based mobile AR applications, which require the identification of the user's location and direction, the devices need to be set with gyroscope and a GPS system. In all cases, all mobile devices will need to have fast CPU, large RAM capacity, a camera and Wi-Fi or 3G enabled internet connection, which will allow the data transmission. It should be noted however that nowadays most latest generation smartphones (if not all) are able to handle mobile AR applications.

STATE OF THE ART

While some years ago, AR applications constituted mainly pilot projects, this is no longer the case today. Technological advances have made possible the development of a number of frameworks and toolkits, which allow the easy development of AR applications. Below we present some of publicly available frameworks:

- **DroidAR** is a framework for the development of AR applications for Android OS mobile devices only. It offers location-based and marker-based AR functionalities (DroidAR, 2011).
- **DWARF**, short for Distributed Wearable AR Framework, develops on the CORBA framework and allows the rapid prototyping of distributed AR applications for mobile computers (laptops and palmtop) (DWARF, 2010).
- **Layar** is today one of the most popular mobile AR platforms, boasting over 10M installs, 9,000 developers and 2,500 individual AR applications, offered as layers. Layar is available for Android OS, iPhone OS, Symbian OS and BlackBerry 7 OS devices, comes globally pre-installed on millions of phones and is promoted by leading handset manufacturers and carriers like Samsung, Verizon and Sprint (Layar B.V., 2011).
- **IN2AR** is a framework that relies on Flash Player for detecting images and markers; as such it operates only across devices able to support Flash Player. IN2AR recognizes natural features, which means that every object or image can be used for detection, as long as it has enough information on it (Beyond Reality, 2012).
- **FLARManager** is a lightweight Flash framework that supports developers in building AR applications. It is compatible with a number of other 3D frameworks and libraries and provides an event-based system for adding, updating and removing markers (Socolofsky, 2009).
- **PanicAR** is a native, customizable framework that allows its integration in extant iOS applications for adding location-based AR features (doPanic, 2012).
- **SudaRA** is a C++ framework based on the ARToolKit. It supports 3D models, sound and multiple-marker tracking among other features. SudaRA is available only for computers, however it offers a simple and well-structured interface (Henrique, 2010).
- **FLARToolKit** is an AS3 port of the Open Source library ARToolKit. It allows marker detection from images and computes the camera position in 3D space. Also, it allows the user to choose among various 3D engines (Saqoosha & Nyatla, 2008).

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Table 1 summarizes the features of the various frameworks.

Table 1 Summary of frameworks

	Location Based	Marker Based	Image Based	Laptops	Palmtops	iOS	Android	Symbian	BlackBerry
DroidAR	X	X					X		
DWARF	X			X	X				
Layar	X					X	X	X	X
IN2AR		X	X	X					
FLARManager		X		X					
PanicAR	X					X			
SudaRA		X		X					
FLARToolKit		X		X					

AUGMENTED REALITY IN TOURISM

A number of applications have been developed based on the available frameworks and toolkits. While many begun as pilot applications or research projects, some of them are today commercially available. Most importantly, however, the examples are extremely varied. This section presents a sample of mobile AR applications, which on the one hand, we consider them to be significantly different from each other, while on the other hand they are all designed specifically for tourist purposes.

Tuscany+, the first AR application, developed specifically for the Tuscany Region by Fondazione Sistema Toscana, operates like a digital tourist guide. Drawing information from internet sources, such as Wikipedia, Google Places and the Region's official portal, Tuscany+ delivers tourist information in Italian and English regarding accommodation, dining, the city's nightlife and of course sightseeing. For the time being, it is available only to iOS (Fondazione Sistema Toscana, 2010). Basel is another city with its own AR tourist guide. Having started as part of the project "Augmented Reality for Basel", it is now accessible through the Layar AR browser discussed previously, as one of the browser's available layers. Therefore, the application is available for iOS, Android OS, Symbian OS and BlackBerry OS. It is available in English, German, French and Spanish and the content is drawn from the City of Basel's dedicated database. The users can retrieve valuable information for the city of Basel and its outskirts, and more specifically regarding its sites, museums, restaurants and hotels, while information for events and shopping centers are also available (mCRUMBS, 2011).

A very different application is Urban Sleuth. Developed by Urban Interactive, Urban Sleuth is designed as a real-life city 'adventure', in which users participate with the aim to solve mysteries and carry out missions while travelling around the city, competing each other or in teams. Through the application, the real world blends with the virtual, and the offered 'missions' can be designed so that participants can discover neighborhoods and historical monuments, among other interesting locations (Urban Interactive, 2010). The StreetMuseum application, developed by Thumbspark Limited specifically for the needs of the Museum of London, offers users the chance to visualize the city of London at various points of history. Tourists can point the camera of their mobile phones to present day street views, and have historical pictures, drawn from the Museum's vast collection, superimposed on top of their real view, while additional information is also available through information buttons. StreetMuseum offers also a trail functionality in which tourists can design their route beforehand and discover the city's history or identify altered landscapes and important landmarks (Thumbspark Limited, 2010). Table 2 presents in short the coverage and the availability of the discussed applications.

Table 2 Applications' coverage and OS availability

	Place	iOS	Android OS	Symbian OS	BlackBerry OS
Urban Sleuth	Urban locations/ world wide	X			
Tuscany+	Tuscany Region	X			
Basel AR Tourist Guide	Basel	X	X	X	X
StreetMuseum	London	X	X		

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BENEFITS FOR TOURISTS – AN ENHANCED EXPERIENCE

As Garcia-Crespo et al. argue, the tourism industry is currently in need of technology-based integrated value-added services, which are highly dynamic and offer interactivity and entertainment (García-Crespo et al., 2009). Augmented Reality has proven so far to be a technology that can provide tourists, and citizens of course, with much more personalized content and services tailored to their particular needs. Specifically, AR tourist guides are able to display content upon request as tourists travel around the city, exploring the cityscape and the sites. As such, one could say that mobile AR applications allow users to explore the world by adding new layers to their reality, thus resulting in a new interactive and highly dynamic experience. Moreover, as these applications are in most (if not all) occasions accessed over mobile devices with GPS functionalities, tourists can gain additional benefits and navigate themselves interactively with the help of the direct annotations of the selected locations.

In addition, information within an AR application is delivered through the use of various multimedia formats. Such formats, as explained, range from sound and image to video clips, 3D models and hyperlinks that may direct the user outside the application. The combination of AR technology, the availability of such multimedia and the careful design of the mobile application can altogether allow tourists to create lists of their favorite POIs equipped with embedded information, i.e., the aforementioned multimedia files. Further to this, it should be noted that, while geo-location and AR tags may trigger the delivery of multimedia content, the content itself could be designed so as to provide further connectivity between the AR application and others, thus offering additional benefits to tourists. For example, AR can superimpose layers of information drawn from online social networks, while at the same time offering a built-in solution for directly updating the user's social network account(s). As a result, a tourist may instantly share or exchange information and tips and express her/his opinion with others within the application or outside, over a much larger network. This suggests that such mobile AR applications can offer further added value to tourists by introducing the concept of connectivity and sharing of experiences.

Moreover, a mobile AR application, being highly portable, can function as a tourist guide that delivers information upon request, thus minimizing, on the one hand, the effect of information overload and on the other hand the effect of irrelevant information. Information overload can occur when tourists are overwhelmed by the transmitted information regarding historical sites, museum exhibitions, the pace of the navigation and so forth. Information overload's effect further increases when the user considers the information redundant or beyond her/his particular knowledge level (Oppermann & Specht, 1999). AR can help significantly museums, heritage sites, cities, and tourist professionals in general, exactly because information can be organized and transmitted in layers or upon request. This suggests that information can be targeted according to one's knowledge level and interests, age, profession and so forth. As a result, mobile AR applications can personalize the visit, according to tourists' desires and expectations, resulting in a much more memorable experience (Sparacino, 2002).

AN ARCHETYPAL MOBILE AR APPLICATION FOR TOURISM

As illustrated, the applications of AR within the tourist sector are extremely varied and each is designed to satisfy different needs. Yet, in essence, a mobile AR application needs to take into account the particular needs of tourists and the organization's potential to maintain and manage it. This section presents an archetypal framework for the development of mobile AR applications, with the aim to analyze the design processes. It includes X steps, namely the representation of the situation, the mental model, the activity model and the design of the class diagram, which will represent the class structure of the system.

During the design process, the first step is to represent the current situation that depicts both types of users, i.e., the tourist and the System (mobile AR application) Provider, who in this case can be a museum, a city council, a heritage site and so forth. Figure 1 presents an illustration of both sides' needs, as well as their relationships.

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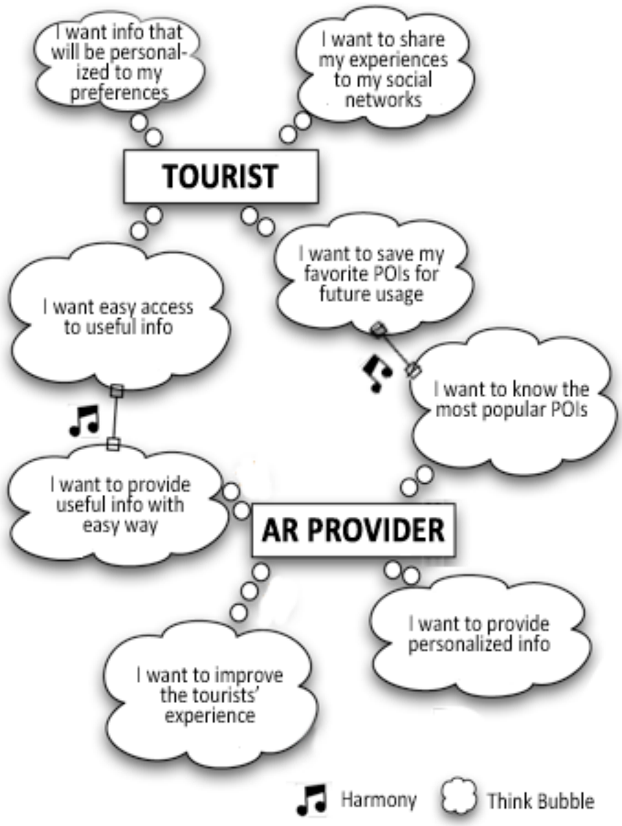

Figure 1 The thoughts of Tourists and AR System Providers

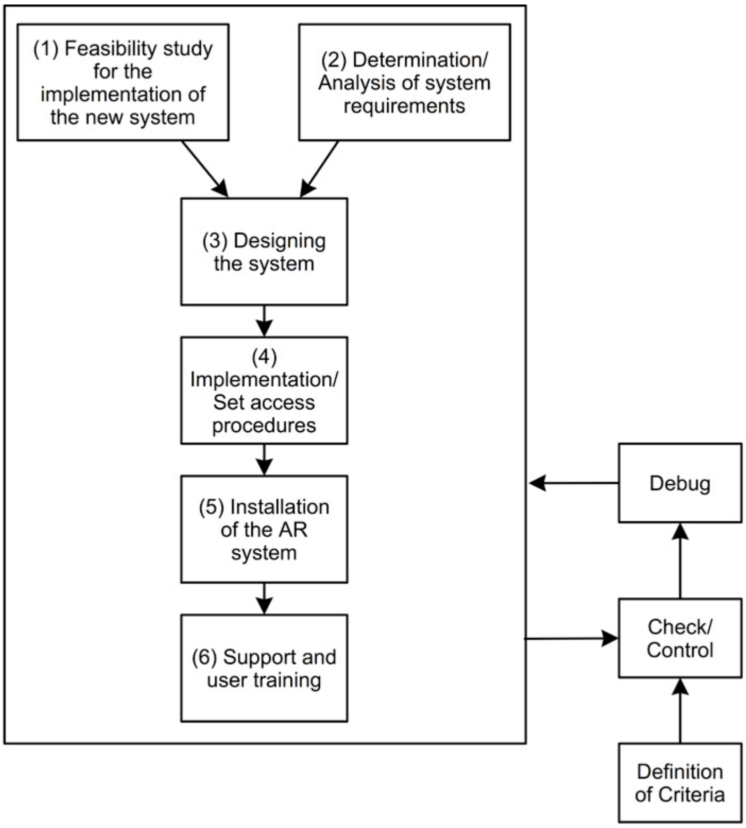

Figure 2 The Activity Model describes the process of AR system development

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Table 3 Criteria for performance measurement

Efficacy Does it work?	• Does the system work correctly? • Does the system provide the required information to the correct users? • Are data being registered correctly in the database? • Are restrictions, the plan of completeness and the frameworks confirmed?
Efficiency Does it use minimum resources?	• Is the utilization of human resources better/ adequate? • Dos hardware systems work correctly and according to the main plan? • Is the tourists' experience more efficient according to statistics/ surveys? • Are the capabilities of existing IT systems and AR application fully exploitable?
Effectiveness Is this the right thing to be doing? Does it contribute to the wider purpose?	• Does the new system contribute effectively to ensure the smooth running of the organization in achieving its objectives and improve its image? • Does the new AR system provide better tourist support?

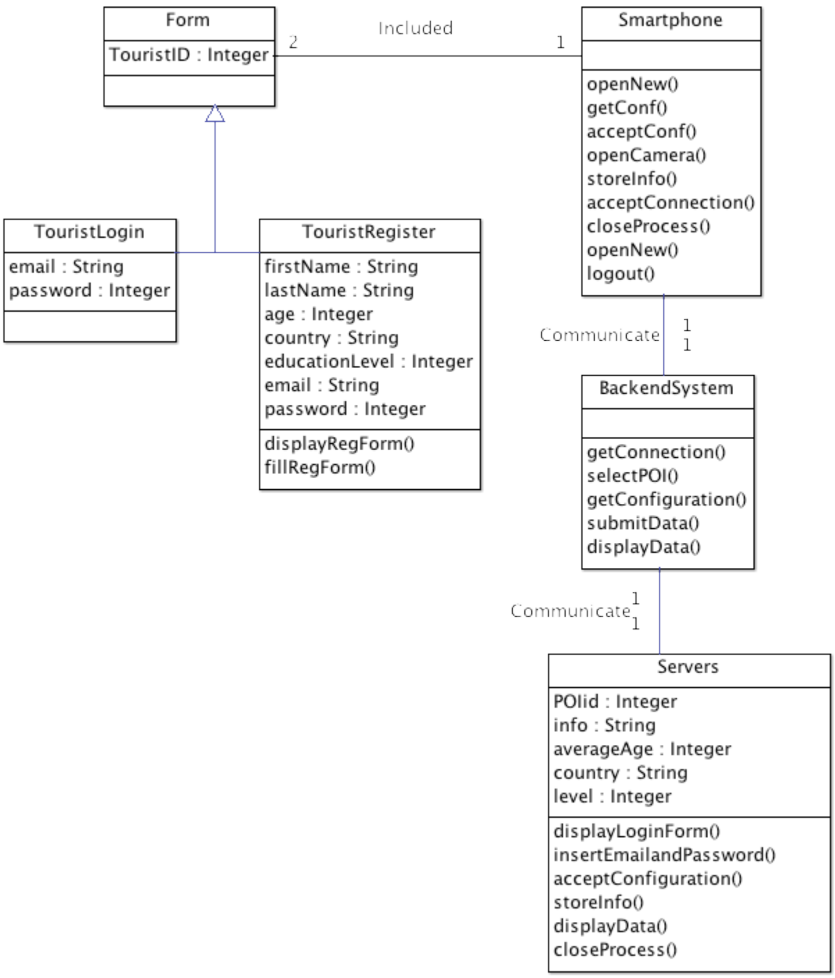

Figure 3 The Class Diagram represents the crass structure of AR System

After having analyzed the current situation, its representation needs to be transformed into the mental model. This is based on six different, consecutive processes; a feasibility study for the implementation of the new system; a system requirements analysis; the design of the system; the implementation procedures; the installation of the AR system; and finally the training of those operating the system. Next, the activity model describes the steps that need to be followed up to the final implementation and prescribes the stages of the analysis and the development of the system (Langer, 2008). This is depicted in Figure 2. At the same time, in order to assess the performance, it is necessary that a set of criteria is set beforehand, against which the efficacy, the efficiency and the effectiveness of the developed system will be measured. These are summarized in Table 3.

Next, one needs to design the class diagram of the system's class structure. Undoubtedly, there are many factors that one needs to consider and the class structure largely depends upon the functionality of the

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mobile AR application. As a result, we present here a generic structure, which we believe it contains the most pertinent information, which is also expected to be to a large extent similar across most mobile AR applications. It contains the following main classes: TouristLogin, TouristRegister, Form, Smartphone, BackendSystem and Servers, and each class has attributes and operations (Figure 3).

OBSTACLES & FUTURE DIRECTIONS

As technological advances made easier the development of mobile Augmented Reality applications, AR escaped the confines of laboratories, research and academic institutions and is publicly available across all application stores. However, there are some important difficulties that hinder still the full exploitation of the technology's potential. One such major obstacle of mobile AR technology is the lack of interoperability across mobile platforms. This suggests that, even though there are many frameworks and toolkits for developing mobile applications based on AR technology, still these applications cannot be used across all operating systems. In addition, the AR applications for the tourist sector most often require an internet connection. Obviously, this is possible through Wi-Fi or 3G. However, not all cities or sites are fully covered with Wi-Fi networks offering free internet connection, and 3G and data roaming charges are still a considerable expense for many tourists, especially for those of younger age.

As such, future research within the particular field should be focused on the interoperability of frameworks and toolkits. It is necessary that a cross-platform framework is developed, one that will benefit developers, service providers and of course users. While an internet connection will be always needed for additional connectivity purposes or for downloading external content, offline mobile AR applications are still a viable solution. Such solutions will allow users to avoid additional charges without losing anything from a fully personalized, interactive and enhanced tourist experience.

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