AUGMENTED REALITY IN TOURISM – RESEARCH AND APPLICATIONS OVERVIEW

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ABSTRACT

Augmented reality is a complex interdisciplinary field utilizing IT technologies in diverse areas such as medicine, education, architecture, industry, tourism and others, augmenting the real-time, real-world view with additional superimposed information in chosen format(s). The aim of this paper is to present an overview of both research and application aspects of using augmented reality technologies in tourism domain. While most research, and especially applications, are dealing with and developing visual-based augmented reality systems, there is a relevant amount of research discussing the utilization of other human senses such as tactioception and audioception, both being discussed within this work. A comprehensive literature analysis within this paper resulted with the identification, compilation and categorization of the key factors having the most relevant impact on the success of utilization of augmented technology in tourism domain.

KEY WORDS

CLASSIFICATION

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INTRODUCTION

In the augmented reality environment user is presented with a real-world view in real-time, but artificially augmented with information that is generated and superimposed by a specific computer system including but not limited to digital images, videos, texts, sounds, GPS location data, tactile vibrations, and similar. The information about the world may become interactive and possible to manipulate with. The augmented reality applications include numerous fields, such as medicine [1-4], architecture [5, 6], education [7-9], industry and robotics [10,11], entertainment, military, and others.

A more recent study exploring the versatility of applications of augmented reality is presented by Billinghurst et al. in [12], but also a less recent, but equally valuable contribution is made by Yu et. al [13], including application, limitation and future direction review of augmented reality.

At this point, it is important to explicitly distinguish the augmented reality from a concept of virtual reality. While virtual reality uses exclusively virtual surroundings (computer-generated graphics, animations and other information), augmented reality uses real-world surroundings, augmented with virtual objects [2] in real time.

Physical environment can be augmented via any human sense [14], including sight, touch, hearing, taste and smell, although the most commonly used augmentations up to date are visual and auditory, with visual displays having a "pivotal role in supporting the spatial on-trip activities of tourists" [15]. This paper will present both systems based on visual information, and systems based on other sensory input researched and/or developed in the tourism domain.

AUGMENTED REALITY IN TOURISM

Augmented reality has the potential to improve the tourist experience and help tourists to access relevant information, thus improving their knowledge regarding their touristic destination, while increasing levels of user's entertainment throughout the process [16]. The information provided to users via augmented technology may be context-aware and personalized to user's characteristics and needs.

Yovcheva et al. [17] define the augmented tourism experience as a "complex construct which involves the emotions, feelings, knowledge and skills resulting from the perception, processing and interaction with virtual information that is merged with the real physical world surrounding the tourist.", arguing that the topic of experiences (expected and actual) from using the augmented reality technology in the context of tourism is still not sufficiently researched.

Utilization of augmented reality in tourism context proved to be a promising path in several existing papers such as [14, 18], was being a target application context in earlier research efforts [19-21], but also in more recent work on augmented reality context, such as [22, 23].

Garcia-Crespo et al. argue that the tourism industry is currently in need of highly dynamic, interactive and entertaining technology-based integrated value-added services [24]. The same authors present the developed SPETA system, which provides recommender services based on the knowledge of user's preferences and current and past locations.

Kounavis et. al discuss the use of augmented reality applications in the tourism context, addressing the technical aspects of mobile augmented reality application development, but also examining the state of the art of such developments and propose an archetypal

framework for the development of mobile AR applications [25]. Their research is limited exclusively to augmented reality mobile application development, but they argue that several examples have shown that augmented reality "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."

The main issues with the mobile AR technology authors recognize in mobile hardware requirements (fast enough CPU, large enough RAM capacity, camera, continuous WiFi and/or 3G connectivity, etc.), and, more importantly, in interoperability issues emerging across mobile platforms, and although there "are many frameworks and toolkits for developing mobile applications based on AR technology", the developed applications cannot be used in all the relevant mobile operating systems.

Table 1. Availability of frameworks through mobile operating systems [25].

	iOS	Android	Symbian	BlackBerry
DroidAR		X		
DWARF				
Layar	X	X	X	X
IN2AR				
FLARManager				
PanicAR	X			
SudaRA				
FLARToolKit				

The Archeoguide project has delivered a personalized electronic guide and tour assistant to cultural site visitors, providing a walking experience through a cultural environment in order to have the possibility of observing the real world, with visualizing 3D reconstructions of monuments and thus acquiring additional information during the visit [20, 26].

Fritz et. al describe the development of an AR interactive visualization system based on the concept of tourist binoculars and with integrated AR scene enhancements within the tourist application [16]. The focus idea is for the user to retrieve personalized multimedia information by means of user-friendly interface, thus aiming to increase the overall touristic experience.

Authors list several other examples of using the augmented reality technology in tourism, namely, augmented walks, where tourists are placed within the real environment, but with the possibility to view additional artificial information in the form of 3D reconstructions of monuments, either via digital screens, or head-mounted displays. Within the "Ename 974" project, the system superimposes the real-world scenes with virtual 3D reconstructions of archaeological monuments; the results are displayed on a visualization device [27].

According to [16], several national parks in the US have also "added augmented reality stations to view archaeological sites on far distant cliffs and other inaccessible locations". The devices enabling the augmented reality experience are telescope-like and are superimposing animations on the real-world scenes, providing virtual recreations and information on real fossil remains.

Smartphones represent the first medium with the potential to introduce augmented reality to the mass market, which has a significant impact for augmented reality tourism applications [28-29].

This potential rises from the facts that smartphones combine all the necessary technologies for enabling augmented reality applications, in one pocket device, unlike head-mounted displays or full-sized computers or laptops.

Yovcheva et al. claim that, in the context of mobile augmented reality applications, the effective and usable design is still "at its infancy", and cover the overview and evaluation of 22 smartphone applications in their work, outlining "tourism-related domain-specific design challenges" [30]. The selected criteria for comparative overview and evaluation of smartphone augmented reality applications is presented in Table 2.

Table 2. A selected criteria for comparative overview and evaluation of smartphone augmented reality applications for tourism [30].

Functionality	Description
1. **Search and Browse**	Search and browsing (categorical search) mechanism provides access to relevant information (Rasinger et al., 2009).
3. **Context-aware push**	The tourist may miss out on important/interesting information, especially in information-rich urban settings (Raisnger et al., 2009).
4. **m-Commerce**	The possibility for booking/reservation and payment (Rasinger et al., 2009).
5. **Feedback**	A mechanism to provide and/or receive feedback from/to other tourists or tourism authorities (Rasinger et al., 2009).
6. **Routing and navigation**	The possibility to obtain directions and navigation to a POI, once it is visualized in AR view and selected (Umlauft et al., 2003).
7. **Tour generation**	Adding POIs to a (pre-generated) itinerary allows tourists to plan better and manage their leisure experience (Umlauft et al., 2003).
8. **Map services**	Helps tourists to obtain an overview of a larger territory (Suh et al., 2010).
9. **Communication**	Option to realize direct contact with accommodation providers, exhibition owners and others involved in service provision (Rasinger et al., 2009).
10. **Exploration of visible surroundings**	Apart from looking up for information about a particular item, place, object and category, tourists may wish to "explore" available information about their surroundings without pre-defined criteria (Ajanki et al., 2010).
11. **Interactive AR view**	A "clickable" AR view could serve as an interface to additional, more detailed information about a point of interest (Wither et al., 2009).
12. **Filtering of AR content**	The option to filter and change interactively the visualized content in AR view. This is an important feature, keeping in mind that urban environments are rich in potential targets for annotation (Tokusho and Feiner, 2009)

Authors conclude the applications' review with notes that current smartphone augmented reality applications provide tourists with location-specific information regarding the user's current surroundings, enable updated access to variable content, enable flexibility when delivering text and/or multimedia information and provide interactive annotations on top of map-based services. However, authors further argue that some relevant functionalities are still missing, such as context-aware push of information, feedback, routing, m-commerce, context awareness, and similar.

Further research into the mobile augmented reality application is presented by Han et al., who are investigating tourists' requirements for the development of a mobile AR tourism application in urban heritage, in the Dublin context [31]. The investigation was performed by in-depth interviews with 26 international and domestic tourists visiting Dublin city. Authors note that the "technology is just on the verge of being implemented in a meaningful way in the tourism industry", passing the initial hype stage. One of the main concerns is the non-interactive aspect of pushing the information to users.

The same authors argue that the end-user point of view has been neglected when developing augmented reality applications for tourism context, and therefore their research aims "to

identify and analyse tourist requirements to implement Augmented Reality technology in Urban Heritage". The results of their study showed several relevant aspects which could lead to better understanding and development of augmented reality applications for users; first, users (tourists) require a source of local and updated information which resides within the context and timeframe of their visit; the social networking functionality including reviews and suggestions from other users are widely used and could facilitate repetitive use; simple navigation and the design of user interface proved to be key factors for continuous use of augmented reality application.

In order to enhance visitor experience, museums are also preserving media such as radio, movie clips, photography, and one of the illustrative examples is the use of a guidebook in a historic home [32].

Augmented reality also tackles outdoor navigation where [33] demonstrate the use of augmented reality for collaborative navigation and information browsing tasks in an urban environment, having a direct impact on tourism domain. The information is presented to users via a head-mounted display, overlaying the real-world with a combination of text, graphical objects, 3D objects and images. Both navigation and information browsing functions support collaboration.

Some research on augmented reality in tourism context is focused on usability aspects and cognitive issues [34], but there is also research targeted towards expected user experiences from using augmented reality technology [35] and actual experiences [36]. Olsson et al. [37] documented captivation, motivation, engagement and novelty as some of the more relevant characteristics of expected user experiences with using augmented reality technologies.

Yovcheva et al. [17] have also worked on conceptualization of augmented tourism experiences, describing the main characteristics of augmented tourism experiences and outlining the framework consisting of "most significant determinants of augmented tourism experiences". The aim of the paper, according to authors, is to set directions for further research of augmented reality in the tourism context, but also to provide concrete help for designers and developers in engineering augmented tourism experiences.

The same authors have listed characteristics of augmented tourism experiences, their potential use within the tourism domain and examples of already developed AR systems. These characteristics include awareness, efficiency, empowerment, engagement, fun, liveliness, meaningfulness, motivation, novelty, playfulness and entertainment, safety, surprise, tangibility. Fig. 1. illustrates authors' developed framework for engineering augmented tourist experiences.

Authors conclude that the value that augmented reality systems facilitate in the overall tourist experience is determined by the fit between context and content, referring to the spatial, temporal, personal, and technical context where the AR system is being used.

Non-visual aspects of the augmented reality utilization within tourism context are discussed within several following papers.

Wei et al. [38] discussed haptic display and audio display, with their combination evaluated in representing tourism information to users with a mobile phone. The results of the study showed that information represented in the combined haptic-audio display yielded highest identification rate (86,7 %), while "no significant effect was found for rhythm or amplitude alone".

PocketNavigator [39] is a pedestrian navigation application with implemented tactile compass, which is using vibration patterns for navigating users to destinations.

Giachritsis et al. presented a method for developing tactile navigation patterns in context of basic directions, landmarks and actions [40]. Authors found that simple directions were simpler to identify in comparison to actions or landmarks.

Tactile displays for pedestrian navigation were also researched by Srikulwong and O'Neill [41]. The results of their study showed that, when using wearable tactile displays for pedestrian navigation, users' navigation accuracy was equivalent to that with a visual-based system, and that the route's completion time was significantly faster.
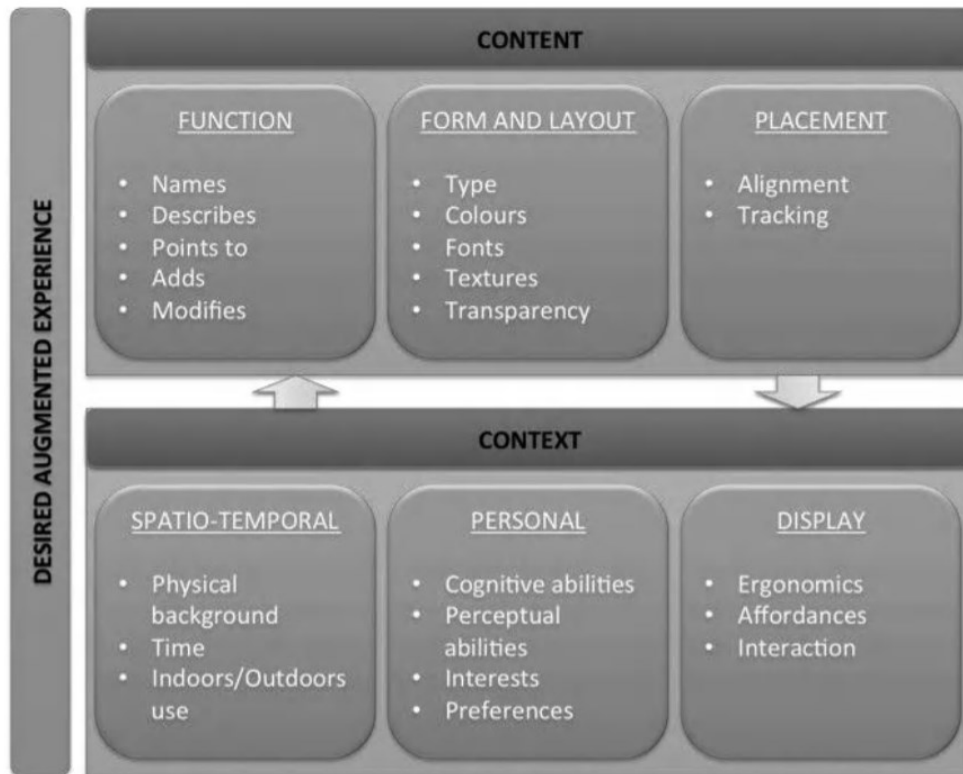

Figure 1. Framework for engineering augmented tourist experiences [17].

OVERVIEW OF RELEVANT FACTORS

Several identified dimensions and factors having a direct impact on the success of utilizing augmented reality technologies in tourism domain have been identified and extrapolated by the relevant literature analysis presented in the previous section. The factors were categorized within several dimensions: general requirements, functionalities, issues, overlay types and technologies, as presented in Table 3.

The key requirements for the augmented reality applications include dynamics, interactivity (push-only content proved to be inadequate in this context), entertainability, strong connection between user context and delivered content (delivered content should be up-to-date, real-time, local, and context-sensible in general), intuitive and adequate user interface avoiding cognitive overload, simple navigation within the application for effective application utilization. Functionalities are mostly extrapolated from [30] and supplemented with additional ones which were identified in the analysis process. Browser and search functions enable navigating through relevant content and finding the one which is relevant to the user. Map services include map browsing, routing and navigation, and are closely related to automatic tour generation for the user exploring the area of interest. Map services can also be associated with social networks, which might include feedbacks and various users'

discussions on related content. Communication enables direct channels to service providers, agents, and/or other users, etc.

Overlay types include identified sensory inputs which are currently in relevant use. Those include text, graphics, videos, sounds, and tactile input (vibration patterns for example).

Table 3. Identified dimensions of using the augmented technology within tourism context with related factors.

General Requirements	Functionalities	Issues	Overlay Types	Technologies
● Interactivity ● Dynamics ● Entertainability ● Context-content correlation ● Intuitive user interface ● Simple navigation ● Captivating, motivating and engaging content [37] ● Awareness, efficiency, empowerment, engagement, liveliness, meaningfulness, motivation, novelty, safety, surprise, tangibility [17]	● Browse, search ● Map, routing, navigation ● Communication ● Context-aware push ● Mobile commerce ● Social networks ● Collaboration ● Tour generation ● Recommender services	● Hardware requirements ● Device-specific challenges ● Interoperability ● Portability ● Ease of use ● User comfort ● Accessibility ● Push-only ● Safety	● Text ● Graphic ● Video ● Audio ● Tactile	● Handheld integrated ● Head-mounted ● On-site static peripherals ● Site-related mobile

Technologies are categorized on several types, such as handheld devices with integrated technologies such as display, GPS, gyroscope, compass, accelerometer which include smartphones, tablets and similar; head-mounted devices such as HUDs, lenses and similar; on-site static devices such as monitors, projectors, speakers, binoculars, and similar; on-site mobile devices where the AR environment is for example embedded within the tour vehicle; etc. Issues can be identified in hardware requirements (RAM, CPU, display resolution, sensors, etc.), hardware-specific challenges (for example, using mobile phone as an AR device requires constant holding of the device in front of the user, affecting the comfort and safety requirements; distorting effect of the phone's camera is changing the real-world view as seen through the eye; etc.), interoperability of the applications through the number of platforms (incompatible hardware platforms or operating systems for example), portability of devices, comfort and safety in using the devices, questions of accessibility for persons with damaged and/or non-functional senses, and non-interactive nature of push-only content. To address all these issues in an augmented reality environment might prove to be a challenging task, but ultimately would lead to a more successful utilization of the AR technology in tourism domain.

CONCLUSION

This article presents an overview of past and present research and applications in utilizing the augmented reality technologies in tourism context, while identifying and categorizing key factors having the most significant impact on the successful utilization of such applications. Identified factors are listed within several appropriate categories: general requirements, functionalities, issues, overlay types, technologies, and present a clear starting point for the future overviews, research and developments within the area.

While most of the research and applications are oriented towards augmented visual overlays, a certain amount of papers is dealing with non-visual inputs such as audio and haptic, which might be comparably effective in certain use-case scenarios (routing for example), but with the potential to have considerably less distracting elements in comparison with the visual overlays, thus positively affecting, for example, the safety requirement. Such technologies are currently in need of further development and research in order to reach the availability and utilization level of visual-based applications and devices, but certainly have the potential in the field domain.

The Introduction section of the paper overviews the augmented reality technology in general, clarifies the distinction between the augmented reality and virtual reality, and gives an overview of related work.

The Augmented Reality in Tourism section provides a comprehensive literature overview of research, technology and application developments in the context of utilizing the augmented technology in tourism domain.

The Overview of Key Factors section identifies and elaborates those key factors having a critical influence on utilizing the augmented technology in tourism domain, and categorizes them in several appropriate groups, namely, general requirements, functionalities, issues, overlay types and technologies.

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