Augmented Reality for Cultural Heritage Communication and Education

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Augmented Reality (AR) applications are increasingly used in many research and commercial fields. Some of the fields that these applications are used are recreational digital games, tourism, education, and marketing. Location-based augmented reality is a type of AR that typically runs on mobile devices (smartphones or tablets) and uses the device's GPS sensor to guide users to specific locations. When these locations are reached the users are presented with informative digital content. Location-based augmented reality (AR) applications for cultural heritage communication and education are created to inform the public about cultural heritage monuments in an engaging and entertaining way.

location-based augmented reality | cultural heritage education | cultural heritage communication

1. Introduction

Location-based augmented (LBAR) applications have existed for quite some time, but their use for various communication purposes has become widespread after the advent of two popular augmented-reality location-based games, namely Pokemon Go and Ingress, created by Niantic in 2014 and 2016, respectively. Location-based augmented reality apps (also called location-aware augmented reality) are currently used in a number of fields, such as entertainment, education, and marketing. An application can also be used to fulfill more than one purpose. For example, an LBAR mobile application can be used for tourism marketing, but at the same time, it can also provide information that educates visitors about a tourist destination.

Location-based augmented reality applications typically run on mobile devices (smartphones or tablets) and make use of the GPS sensor of the mobile device to guide users to specific locations. When these locations are reached, digital content is activated. Digital content can be in many forms, such as text, video, 2D and 3D graphics, and animations. Location-based augmented reality can also be combined with image-based augmented reality to superimpose the real world with digital content when specific locations are reached, and the camera of the mobile device is pointed at objects from the real environment (e.g., constructions, monuments, etc.) [1].

Cultural heritage communication is increasingly taking advantage of innovations in digital technologies, and LBAR applications can be utilized for creating informative cultural tours. Using LBAR applications, users are prompted to visit cultural heritage monuments and places where significant historical events have occurred. When the users get close to these locations, digital content appears on the screens of their mobile devices, informing them about various aspects of these locations, such as historical facts, architectural and artistic trends related to human constructions, etc. Applications designed for augmenting the environments with cultural heritage content are numerous. Overlaying the physical world with historical information is present in many initiatives (e.g., [2][3][4]).

2. Location-Based Augmented Reality for Cultural Heritage Communication and Education

Augmented Reality (AR) has a long history. The following part presents some important milestones in the AR evolution.

2.1. Important Milestones and Types of AR

The first AR technology, an AR head-mounted display, was developed in 1968 at Harvard [5] by a scientist called Ivan Sutherland. The head-mounted display was called “The Sword of Damocles”. AR technology evolved through the efforts and scientific achievements of academia and the computer industry in the decades to come. In 1974, a laboratory called Videoplace was built. Videoplace combined projectors with video cameras to create an artificial reality. However, it was not until the 1990s that AR experienced significant growth. In 1990, the term augmented reality was coined by a Boeing researcher named Tom Caudell, and in 1992, the first immersive and fully functional augmented reality system called “Virtual Fixtures” was developed by Luis Rosenberg. A few more important advancements took place in the 1990s. In 1994, the first augmented reality Theater production was created, titled “Dancing in Cyberspace”, featuring real acrobats dancing within and around virtual objects on stage. In 1998, the 1st & Ten line system was introduced by SportsVision. The system augmented the live broadcast display of American football fields with yellow lines to help the viewers understand the game’s progression. In 1999, NASA created a hybrid synthetic vision system for their X-38 spacecraft, an experimental vehicle, to assist navigation [6].

In the following decades, the growth of AR was even more remarkable. A significant milestone in AR evolution was in 2000 when an open-source library called AR toolkit was released, providing developers with tools for rapid augmented reality application development. In 2009, Esquire magazine introduced AR in print media, and in 2013, Volkswagen created the MARTA app, which gave technicians step-by-step instructions by augmenting the vehicle parts with text and animations. In 2014, Google introduced its augmented reality glasses, and in 2016, Microsoft started shipping its AR head-mount device HoloLens [6].

Quite a few categorizations have been presented throughout the evolution of AR. One categorization is based on the devices that enable an AR experience. AR can be achieved through wearable and non-wearable devices. Wearable devices include headsets and helmets, and non-wearable devices include mobile devices (smartphones, tablets, etc.), stationary devices (TVs, PCs, etc.), and head-up displays (integrated or retrofitted) [7]. Another taxonomy concerns the way the in which the AR experience is triggered. Marker-based AR, also referred to as image-based AR, relies on visual markers (e.g., QR codes, printed images, real-world objects, etc.) to trigger the experience. Markerless AR, on the other hand, does not rely on physical markers. Instead, mobile device cameras and other sensors are used to detect and track the user’s environment and determine the place where the virtual content will appear. Two common types of markerless AR are projection-based AR and location-based AR. Projection-based AR uses projectors to display multimedia content (e.g., 3D images) onto flat two-dimensional surfaces, such as building walls. In location-based AR, the content is fixed to a specific physical location. Mobile devices with GPS sensors are the most common way to identify specific locations and superimpose the real environment with multimedia content through the mobile device camera. The multimedia content can be in the form of text, images (3D and 2D), sound, videos, and animations.

2.2. AR in Education

Today AR is being utilized in many industry sectors. For example, tourism is an industry sector exploiting AR technologies' potential for marketing and educational purposes. Education is a sector that also benefits from AR, and by exploring the literature, one can find a wide variety of applications that have been applied at all levels of education.

For example, AR applications are being developed for primary education [8][9][10], secondary [11][12], and tertiary education [13][14]. Augmented reality is also used for adult learner education and special needs education [15][16]. AR has also been used to support a wide range of subjects, as can be seen in a recent literature review [17]. These subjects include language learning [18], mathematics [8][19][20], chemistry [21][22], computer science [23][24], engineering [25], history [2][26], physics [27], STEM subjects [14][28], biology [29][30], and environmental education [31].

A relatively recent systematic review and meta-analysis of AR in educational settings shows a remarkable increase in research studies between 2012 and 2018 [32]. According to this review, many studies reported the advantages of using AR in educational settings. These advantages refer to positive effects on learning gains and student attitudes, such as improvement of academic performance, motivation, creativity, and autonomy. However, some disadvantages were also reported in the studies examined in this review paper. The most reported disadvantage was the complexity of using AR, especially when the target group was children. New technology, such as AR, can be complex, especially when the users do not have technological expertise. The rest of the issues encountered are also associated with this complexity. Technical difficulties were reported by teachers when using AR in their classrooms. Another reported problem was multitasking. Students expressed that these applications demand too much attention, which can cause students to omit essential instructions. Finally, resistance from teachers has also been reported as an issue. Some teachers prefer having total control over the content, despite the benefits of AR applications in learning gains and motivation.

AR has also proved successful in cultural heritage education and communication [33][34][35]. AR is a valuable technology that can enhance a visitor's experience and knowledge about cultural heritage, and there are several examples of initiatives in this field (e.g., [36][37][38]). Advancements in AR technology, moving from marker-based to marker-less and GPS-triggered overlays, have made AR even more compelling for this field. In addition, Jung et al. [39] conducted a study on cultural differences in AR in heritage sites and found that Western visitors strongly desire to escape reality through AR applications.

A quick analysis of the scientific literature reveals that most AR projects are based on a marker-based approach. For example, a systematic mapping review of STEM augmented reality applications in higher education [14] revealed the scarcity of marker-less AR and location-based applications in the specific field.

Despite its limited use, location-based AR has great potential in cultural heritage communication and education. Location-based AR can help users learn historical facts and other aspects of cultural heritage through visits to urban environments, archaeological sites, and museums. In the following sub-section, some examples of research efforts that focus on this specific topic are briefly presented.

2.3. Location-Based AR Initiatives for Cultural Heritage Education and Communication

In [1], the authors developed an educational game that utilizes both marker-based and location-based augmented reality called “The buildings speak about our city”. The game prompts students to explore tobacco warehouses in a city in Western Greece, which pose cultural, historical, and architectural interest. The game also encourages them to find out about the relationship of these tobacco warehouses with the city’s economic and cultural development.

The authors of [40] developed a location-aware AR application that superimposes a 3D model of the past state of a historical building in the real world and allows users to receive historical information in a multimedia form as they walk through the Venetian-style part of the city of Chania.

A location-based Augmented Reality system was developed in [37] to enhance archaeological heritage. The project consists of a mobile app to enhance points of interest (POIs) of the archaeological park of Castiglione di Paludi, Calabria, Italy.

Knossos AR [41] is an outdoor mobile augmented reality guide for the Unesco world heritage site of Knossos, the largest Bronze Age archaeological site on Crete (Greece), considered the oldest city in Europe.

In [42], the authors created BataviAR, a location-based AR application that provides informal learning to tourists visiting the historic site of Jakarta Old Town, and in [43], the authors created a real-time location-based mobile AR system for a cultural site in Mauritius that promotes cultural tourism and enhances the visiting experience.

Another relatively recent example of a location-based AR application for cultural heritage education is presented in [2]. This research paper deals with the development of a mobile location-based AR game that utilizes local history and cultural heritage in the game scenario. The game unfolds in the town of Kemijärvi, Northern Finland, in the 1920s, and its aim is to educate visitors and local residents about the town’s history and cultural heritage.

Location-based AR applications often follow gamification design principles and contain gamification elements [17]. The gamification elements that are frequently encountered in location-based AR applications are points, leaderboards, progress bars, ranks, and rewards [44][45][46][47][48]. Furthermore, gamification design principles include personalization, feedback, freedom of choice, failure, goals, challenges, and social engagement [44][48].

Storytelling and role-play can also be considered as a form of gamification. These applications can also contain digital avatars that can guide the users during the experience, and users can also take on certain roles during the game.

The Geist project was an early attempt to develop a storytelling AR application [3]. The system “GEIST” aims to provide information about historical facts and entertain users by telling stories.

Another early example of an AR location-based game that utilizes storytelling to entertain and educate tourists is REXplorer [49]. REXplorer was specially designed for visitors to the town of Regensburg, Germany. During the AR guided tour, the tourists meet with digital characters through the application and, more specifically, spirits of historical figures that lived in the past. These digital encounters take place in historical buildings of the town. The spirits encourage the participants to complete certain tasks in specific locations within the city center. By performing these tasks, participants indirectly explore the town’s historic city center and learn history entertainingly.

A similar initiative to REXplorer is the SPIRIT research project [50]. Among the project’s aims, one was to develop a location-based Augmented Reality (AR) storytelling application where spirit figures tell stories that occurred during their lifetime at the Saalburg Roman Fort, which is nowadays an outdoor museum site.

Another example of a gamified storytelling AR location-based application is the “unlocking Porto” app [51]. During the location-based AR tour, the player is prompted to visit Porto’s main sights and play small games that appear in the application.

The authors of [52] present Viking Ghost Hunt (VGH), a location-aware adventure game based on a Gothic ghost story set in Viking Dublin. In this game, the users assume the role of a paranormal investigator. The investigator moves around in the city of Dublin, and his task is to hunt ghosts, collect evidence, and solve the mysteries of haunted Viking Dublin. The paper also evaluates the users’ engagement and immersion through qualitative methods.

Location-based AR applications can also be built for tours in interior spaces with the use of beacons as well as other techniques. For example, in [53], the researchers use beacons to develop a museum AR tour guide application that encompasses educational and entertainment functions.

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