2021 6th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM) | 978-1-6654-2742-5/21/$31.00 ©2021 IEEE | DOI: 10.1109/SEEDA-CECNSM53056.2021.9566218

Designing a Cultural Augmented Reality Application For Educational Purposes

Giannis Botilias
Department of Informatics and Telecommunications
University of Ioannina
Arta, Creece
jbotilias @kic.uoi.gr

George Papantzikos
Department of Computer Science
University of Ioannina
Arta, Creece
g.papantzikos@uoi.gr

Athanasios Christopoulos
Department of Computing
University of Turku
Turku, Finland
atchri@utu.fi

Jeries Besarat
Department of Informatics and Telecommunications,
University of Ioannina
jeries.besharat@kic.uoi.gr

Chrysostomos Stylios
Department of Informatics and Telecommunications,
University of Ioannina
stylios@uoi.gr

Abstract. Within the past years, cultural organizations have shown an increasing tendency to adopt technologically innovative solutions in their activities. This shift is attributed to the wider technological evolution, in general, and the manifold capabilities that modern mobile devices have, in particular. Augmented Reality (AR) applications constitute a typical example of an interactive solution which has been already applied in various domains (such as, recreation, education). Motivated by the wider adoption that this technological solution has received, this article discusses the design and the developmental steps followed to create an AR (marker-based) application, which is dedicated to the medieval castle of Arta in Greece. The application has been developed using the Unity 3D platform and the Vuforia Software Development Kit (SDK). As part of our ongoing research and development efforts, our future plans include the empirical evaluation of the developed application. In addition, we hope that the presentation of this work will motivate cultural organisation to consider the adoption and the use of the AR technology as a means to complement and enhance the visitors' user and, consequently, learning experience.

Keywords. *Mobile AR, Unity, Vuforia, Image targeting*

I. Introduction

In recent years, pervasive computing and the World Wide Web have provided alternative channels for the information and communication exchange. Naturally, this wider evolution has started affecting also the cultural sector, which is now adapting to the new context by adopting novel technological solutions. In contrast to the traditional norms, cultural areas are now being transformed from memory spaces to places oriented to the needs and the expectations that the 21st century visitor has. While keeping in mind the aspect of cultural education, various interactive—usually technologically-aided—solutions have been integrated, as a means to support and promote interdisciplinary information acquisition and exchange. In other words, instead of merely providing visitors' information related to the cultural heritage, professionals in the field are now seeking methods and approach to arouse individuals' interest [1]. In most cases, the integrated approaches are relying on the foundations of the Experiential Learning which promotes active engagement and facilitates the construction of cognitive schemas.

In consideration of this shift, we present an Augmented Reality (AR) application (app) which has been dedicated to the medieval castle of Arta, Greece. The primary objective of this app is to improve visitors' experience, by enriching the topographical and historical elements, with interactive visuals and text-based information. In addition, as with every location-based AR solution, the spatiotemporal restrictions are lifted. The importance of overcoming this barrier (i.e., accessibility) has been linked to increased motivational incentives in exploring and identifying important points that visitors may as well as miss otherwise [2]. Although we acknowledge that the relevant efforts to integrate AR in cultural heritage education are still limited, we hope that more attempts will be made in the near future to ground the use of such solutions in this context as the benefits to the visitors are immense.

II. Related Work

A non-exhaustive search of the relevant literature highlights the necessity of exploring this direction (i.e., the integration of AR in cultural education) as well as the importance of developing such solutions. However, despite the manifold benefits that this technology offers, there are also many shortcomings that developers have to overcome [3]. Therefore, in this section, we summarise the studies that have been conducted by other researchers on the basis of which we designed and developed the present app.

The review that [4] conducted examined the most recent AR applications and their limits in view of interactivity. The outcomes of this work provide insights and recommendations to programmers on how to overcome the most commonly faced obstacles. Studies that have investigated the potential of mobile Augmented Reality (mAR) in cultural spaces and monuments highlight the factors that affect usability (interaction with the interface) and further relate them to technology acceptance [5, 6].

The empirical study that the authors in [7] conducted deployed and evaluated mAR solutions in cultural institutions. The authors discuss the dynamics of these apps in view of their educational potential and value. In a similar manner, the authors

978-1-6654-2742-5/21/$31.00 ©2021 IEEE

in [8] highlight the need to modernize the educational system, in general, and the educational process, in particular. The main argument put forward claimed that mAR has strong pedagogical potential and can bring multiple benefits both inside and outside the classroom.

The authors in [9] compared the design elements of different mAR apps whereas, the authors in [10], enlist the various functions that mobile phones have in view of their potential to support additional design features. In both cases, the concluding remarks provide guidelines for the design and development of interactive and engaging solutions. Finally, the authors in highlight the ethical consideration that surround AR and provide guidelines on how to overcome them.

Although the aforementioned studies constitute only a small sample of the works that are available in the international literature, it becomes evident that the potential of this technology is strong, despite the barriers that developers and users need to overcome.

III. Augmented Reality in Tourism Industry

The rapid development of technology has naturally influenced the tourism industry. Tourism and travel businesses depend heavily on technology to run their daily operations and to provide a better customer service experience. During the planning phase of a trip, individuals feel the necessity to form an idea of their travel destination prior to their journey. It is quite common for travelers to browsing and collecting information about the various attractions of the place that is to be visited. Some of the most advanced technological solutions that support this process are Virtual/Augmented Reality (VR/AR) and, of course, Big Data. All of these technologies share the same goal; to improve the user's experience.

Using AR for tourism marketing purposes is increasingly popular [11]. For instance, in museums, AR applications allow visitors to understand and appreciate the displayed artwork in a fun and engaging way. In addition, they spark their curiosity about the works themselves and encourage them to think beyond them [12].

A. Augmented Reality

Augmented Reality enriches the physical environment with digital data that collectively trigger the human senses. In this way, AR creates a mixed reality that is visible to human in real-time [13]. Contrary to VR, AR augments the physical environment with new content, including text, video, audio, and 3D models, etc. [12].

There are four types that can trigger the augmentation process [14]: *(a)* marker-based (the augmentation is activated by a marker placed in the real-world such as an image or a physical object), *(b)* location-based (the augmentation is activated by the coordinates received from the built-in GPS device), *(c)* dynamic augmentation (the augmentation is activated and changes states in accordance with the object's view while in motion), and *(d)* complex augmentation (a combination of the marker-based, location-based and dynamic augmentation based on digital information access via the internet)

B. Mobile Augmented Reality

Mobile Augmented Reality renders digital (virtual) features on the real-world context [13]. At present, the majority of mAR experiences are provided via smartphones [15]. The mobile devices must have some specific features to work with the AR technology, which are [13]:

- high battery capacity;
- flat touch screen panel;
- rear camera;
- large storage capacity of memory;
- motion sensors (e.g., accelerometer, gyroscope);
- geolocation sensors (GPS) and
- internet connection.

IV. The Augmented Reality Cultural Heritage App

There are many, freely available, AR apps for Android and iOS devices in the respective stores (Playstore - Appstore) with a reasonable portion of them being related to the tourism business [16]. In the current work, we present a cross-platform (Android/iOS) marker-based AR app for cultural heritage. The primary aim of the app is to enhance individuals' experience, while visiting a historical/archeological site in Greece, by increasing their commitment to explore and interact with the various points of interest. To facilitate this goal, various elements have been included which convert the traditional tour into a 'playful' learning experience.

A. Unity 3D

Unity 3D is a platform that provides a powerful graphics engine and a three-dimensional (3D) environment that enables developers to design and render 3D objects, to integrate interactive features and animations using the C# programming language, to manipulate the lighting effects and so on [17].

As a commercial tool it offers a wide variety of both free and priced assets like 3D models, editor extensions, and audio records that save creators time and effort [18]. As a testing tool, the Unity Test Framework package allows users to test their code in both the Edit mode and the Play mode, as well as on platforms such as Standalone, iOS, or Android.

In addition, it allows for different AR toolkits to be integrated as extensions for detecting and tracking image targets required to create AR applications. The most widely used AR SDK are the ARToolkit [19] and the Vuforia [20].

B. Vuforia SDK

Software algorithms and device management are complex parts of AR development. The Vuforia SDK is comprised of two parts: *(a)* the Vuforia Engine and *(b)* the Target Management System [21] which simplify the aforementioned processes. Moreover, the integrated computer vision technology offers real-time 3D graphics recognition and tracking which facilitate further the development of marker-based solutions. For these reasons, Vuforia is considered to be one of the most appropriate tools for handling such processes [13].

This research work is co-funded by the project "Immersive Virtual, Augmented and Mixed Reality Center of Epirus" (MIS 5047221) implemented under the Action "Reinforcement of the Research and Innovation Infrastructure", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund) and co-funded by project: "Enhancing research activities of Laboratory of Knowledge and Intelligent Computing" of the Research Committee of the University of Ioannina."

Besides, a number of resources are provided by the Vuforia SDK—such as camera action, video renderer, custom target, code and target database—for the Unity 3D engine. These resources facilitate the user experience by providing [22]:

- recognition of speed of local targets;
- recognition of a variety of local targets;
- high devotion to target tracking;
- accurate recognition of low-light and partially obscured targets.

C. Developing process and technical aspects

The developing process was conducted in two stages (Fig. 1). The first stage involves processes related to setting up the AR system, such as, creating a targeted image database, downloading it as a unity package) via Vuforia. The second stage involves processes related to using the AR system through Unity3D, such as the integration of database, the programming and modeling processes, and the extracting process of the APK for mobile devices.

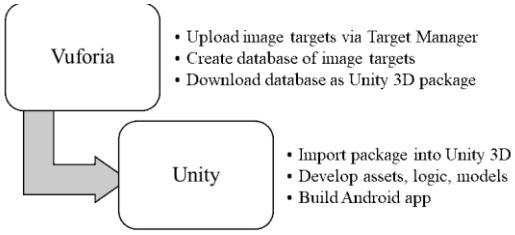

Fig. 1. Overview of the development process.

1) Vuforia plugin

As a first step, image targets were selected to ensure the performance criteria for the Vuforia Engine detection and monitoring. Image targets must have well-lit areas, no repetitive patterns, and the image must be in 8-bit PNG or JPG format with less than 2 MB in size. Subsequently, the images were uploaded on the developer portal of Vuforia which created the database via the Target Manager. Lastly, the database was downloaded in a format compatible to the Unity3D Editor and imported as package.

2) Integration Vuforia in Unity

To use the Vuforia Engine in Unity 3D, firstly Vuforia must be downloaded from the developer portal and, accordingly, should be imported into the Unity 3D editor via the package manager. In this way, Unity 3D is enabled to use the AR camera of the Vuforia Engine as GameObject. Also, a license key must be obtained from the License Manager of the Vuforia website and integrated in the Vuforia Configuration Inspector of Unity. After activating the Vuforia Engine in Unity 3D, the database can be imported as image targets in the AR camera.

Consequently, all targets, app assets, program logic and rendering engine were developed in a Unity 3D project, and, with the help of the Vuforia Engine, the app was ready to recognize the image targets. Lastly, based on the hybrid capability offered by Unity, the process was completed by building the app for Android and iOS devices via the respective modules in the Build Settings that Unity 3D provides.

3) App description

The AR app is based on three scenes with different functions. With the Vuforia SDK, we included image recognition functionalities and the presentation of several features like 3D objects, audio, and text.

The purpose of this application was to provide a new navigation experience inside Arta's castle, presenting information about its history in an interactive and enjoyable way.

The first scene (Fig. 2) is the main menu of the application which includes a redirection link to the *history scene,* a link to the *points of interest*, and information about the *functions of the AR app*.

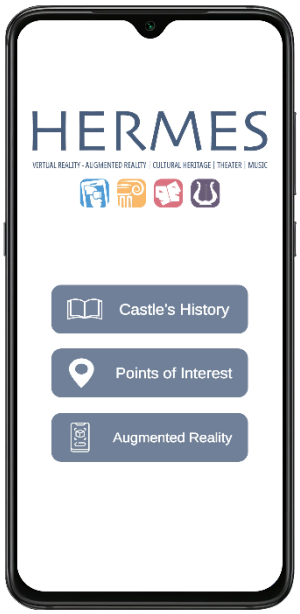

Fig. 2. The menu scene.

The second scene (Fig. 3) is a virtual book which provides information about the castle of Arta (from the medieval era until today) via animations, texts, images, and audio. The book is rendered on a castle room (stone-walls, wooden floor, torches) and includes different interaction mechanisms. To improve the reading experience, Byzantine music is playing on the background.

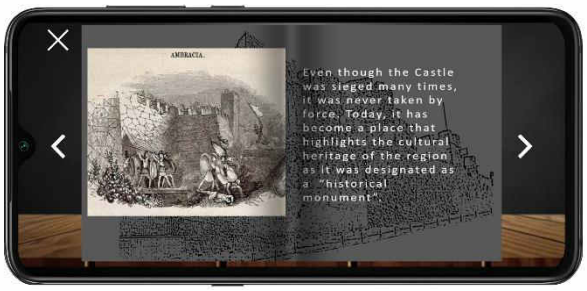

Fig. 3. A history scene as displayed within the app.

The next scene (Fig. 4) renders the 3D model of the castle of Arta. The users can interact with the 3D model (e.g., zoom in/out) and acquire additional information.

Fig. 4. The 3D model scene of the app.

Finally, certain physical objects are augmented with 3D models (overlay) which can be rendered on the mobile phone's screen (Fig. 5).

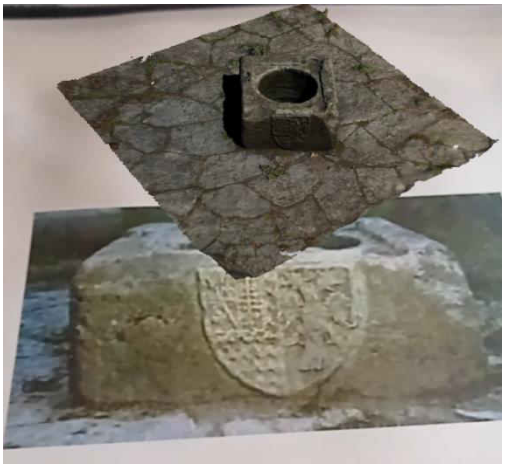

Fig. 5. The Coat of Arms of Arta's Castle rendered as a 3D model.

V. Discussion

Modern digital technologies support the rendering of 3D content which can be utilised to enhance a place's cultural heritage, as discussed in the present case. To this end, unlike the conventional educational technologies (such as computers), mobile devices allow users to access the learning content, independent of the spatiotemporal conditions, in order to explore, observe, and collect data based on their learning goals and needs [23].

The development of an application dedicated to the medieval castle of Arta facilitates learning in a seamless and impromptu way. In addition, it enables users to adapt the pace and the depth of the learning experience. Therefore, while considering the proven benefits of the constructivist approach, in the given example a learning environment accessible using explicitly the users' personal devices (i.e., no additional or specialized equipment), is provided and accordingly, enables users construct their knowledge in accordance to their personal needs and wishes [24]. The aforementioned outcome is achieved in the context of the wider network of interactions that such technology offers (e.g., 3D models, supplementary materials) as well as on the opportunities provided for interaction with other users [25].

VI. Conclusions

This work proposes an easy and innovative way of navigating both archeological sites and other remarkable places. By using AR, the user can explore different places in an interactive and vivid way. Although the application is in the pilot stage, our goal is to evaluate it both with school students, for educational purposes, and with tourists, for marketing purposes.

The potential of AR applications is truly inexhaustible and, when used appropriately, they can greatly affect the educational process and the learning outcomes. Notwithstanding the foregoing, when it comes to the development of AR applications it is important to also consider the ethical challenges and dilemmas that such experiences involve as discussed in [26].

Future works can consider the integration of gamification elements as well as the inclusion of more attractions and cultural points of interest.

VII. References

[1] Kraemer H., 2005: «Το μουσείο του κάστρου Κυμπούργκ: τα υπερμέσα ως μέσο μετάδοσης μουσειολογικής γνώσης», Αρχαιολογία και Τέχνες, τεύχος 95, σελ.,98-100.

[2] Barfield, W. (2015). Fundamentals of Wearable Computers and Augmented Reality, Second Edition. Boca Raton: CRC Press.

[3] Azuma RT. (1997). A Survey of Augmented Reality. Presence, 6.4, pp. 355-385.

[4] Krevelen, D. W. F. Van, & Poelman, R. (2010). A Survey of Augmented Reality Technologies, *Applications and Limitations, 9*(2).

[5] Galatis, P., Gavalas, D., Kasapakis, V., Pantziou, G., & Zaroliagis, C. (2016). Mobile Augmented Reality Guides in Cultural Heritage. Proceedings of the The 8th EAI International Conference on Mobile Computing, Applications and Services.

[6] Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., Ivkovic, M. (2010). "Augmented reality technologies, systems and applications", *Multimedia Tools and Applications, 5*, pp. 341-377, 2011.

[7] Chatzidimitris, T., Kavakli, E., Economou, M., & Gavalas, D. (2013). Mobile Augmented Reality edutainment applications for cultural institutions. *IISA 2013 – 4th International Conference on Information, Intelligence, Systems and Applications*, 270–274.

[8] Nincarean, D., Ali, M. B., Dayana, N., Halim, A., Hishamuddin, M., & Rahman, A. (2013). Mobile Augmented Reality: The Potential for Education. *Procedia-Social and Behavioral Sciences, 103*, 657-664

[9] Herpich, F., Guarese, R. L. M., & Tarouco, L. M. R. (2017). A Comparative Analysis of Augmented Reality Frameworks Aimed at the Development of Educational Applications. *Creative Education, 08*(09), 1433–1451.

[10] Kim, J., Cha, W. and Yoo J. (2011). "The Development of the Augmented Reality Techniques in a Mobile Environment and Active Utilization Plan of the Digital Design", *Korea Digital Design Council, Digital Design Studies*, vol. XIV, no. 30, (2011) April.

[11] Wakefield, C., Simons, A., & John, D. (2019). Can Augmented Reality enhance to a greater visitor satisfaction of historical landmarks?. In GCH (pp. 69-72).

[12] Ding, M. (2017). Augmented reality in museums. Arts Management & Technology Laboratory.

[13] Linowes, J., & Babilinski, K. (2017). Augmented reality for developers: Build practical augmented reality applications with Unity, ARCore, ARKit, and Vuforia. Birmingham, UK: Packt.

[14] Edwards-Stewart, Amanda & Hoyt, Tim & Reger, Greg. (2016). Classifying different types of augmented reality technology. *Annual Review of CyberTherapy and Telemedicine. 14*. 199-202.

[15] Chen, Huixiang & Dai, Yuting & Meng, Hao & Chen, Yilun & Li, Tao. (2018). *Understanding the Characteristics of Mobile Augmented Reality Applications.* 128-138. 10.1109/ISPASS.2018.00026.

[16] Mohd, Nur Shuhadah & Ismail, Hairul & Abd Halim, Norhazliza. (2015). Mobile Augmented Reality: A Tool for Effective Tourism Interpretation in Enhancing Tourist Experience at Urban Tourism Destination. *International Journal of Built Environment and Sustainability.* 2. 10.11113/ijbes.v2.n3.86.

[17] Technologies, Unity. Retrieved from https://unity3d.com/.

[18] Technologies, Powerful 2D, 3D, VR, & AR software for cross-platform development of games and mobile apps. Retrieved from https://store.unity.com/.

[19] Artoolkit. Retrieved from https://artoolkit.org/

[20] Vuforia Enterprise Augmented Reality (AR) Software: PTC. (2021, May 31). Retrieved from https://www.vuforia.com/

[21] Tsai, Chih-Hsiao & Yen, Jung-Chuan. (2014). The Augmented Reality Application of Multimedia Technology in Aquatic Organisms Instruction. *Journal of Software Engineering and Applications. 07*. 745-755. 10.4236/jsea.2014.79069.

[22] Peng, Fuguo & Zhai, Jing. (2017). *A mobile augmented reality system for exhibition hall based on Vuforia*. 1049-1052. 10.1109/ICIVC.2017.7984714.

[23] Martin, F. & Ertzberger, J. (2015). Effects of reflection type in the here and now mobile learning environment. *British Journal of Educational Technology. 47*. 932-944.

[24] Sharples, M., Taylor, J., & Vavoula, G. (2007). A Theory of Learning for the Mobile Age. In R. Andrews and C. Haythornthwaite (eds.) T*he Sage Handbook of Elearning Research*. London: Sage, pp. 221-47.

[25] Martin, F. & Ertzberger, J. (2013). Here and now mobile learning: an experimental study on the use of mobile technology. *Computers & Education, 68*, 76–85.

[26] Christopoulos, A., Mystakidis, S., Pellas, N., & Laakso, M. J. (2021). ARLEAN: An Augmented Reality Learning Analytics Ethical Framework. *Computers, 10*(8), 92.