ISBN 978-987-4417-90-9

ARPOT: an Augmented Reality Platform for Outdoor Teaching

Matías N. Selzer[1,2], Dana K. Urribarri[1,2], Nicolás F. Gazcón[1,2], Martín L. Larrea[1,2], Claudia Sereno[3], Antonela Volonté[3,4], Aldana Mastrandrea[3], and Silvia M. Castro[1,2]

[1]VyGLab Research Laboratory, UNS-CICPBA, Bahía Blanca, 8000, Argentina.
[2]Institute of Computer Sc. and Eng. (CONICET-UNS), Bahía Blanca, Argentina.
[3]Departamento de Geografía y Turismo, Universidad Nacional del Sur (UNS), Bahía Blanca, Argentina.
[4]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Ciudad Autónoma de Buenos Aires, Argentina.

{matias.selzer,mlg,dku,mll}@cs.uns.edu.ar
{csereno,antonela.volonte,aldana.mastrandrea}@uns.edu.ar
smc@cs.uns.edu.ar

Abstract. In the last years, there has been interest in introducing Augmented Reality (AR) into education. However, users who are not technical specialists require tools to facilitate the creation and customisation of AR experiences. Since educational tours and excursions connect students with the concepts taught in classroom, and AR increases the students' interest and motivation, we developed ARPOT, an AR platform for outdoor teaching that integrates tools for the teacher to easily create AR content and tools for students to view and interact with such AR content without internet connection. ARPOT was tested by 240 students of different educational levels at the wetlands of Villa del Mar, Argentina, and 12 new students at the campus of our university. In both case studies, the students reported a more motivating and engaging experience, and the educators reported that ARPOT was a powerful tool for content creation.

Keywords: Augmented Reality; Education; Mobile Learning; Outdoors; Location-based Mobile Augmented Reality

1 Introduction

Augmented Reality (AR) is a technology that merges the real world with virtual objects and, thanks to the advances in technology, it is becoming increasingly popular in many disciplines. AR is particularly relevant for education because it is directly related to Constructivist concepts and situated learning [1, 2], and it provides visual elements and interaction that enhance the learning process.

AR has vast implications and numerous benefits for the augmentation of teaching and learning environments. According to [3], AR has the potential to:

Fig. 1: ARPOT in use. The icons are always fixed in the corresponding place, even when the user walks and rotates. A small label also shows the distance between the user and the point-of-interest. (Left) Student looking for a particular point-of-interest. (Right) Device view.

engage, stimulate, and motivate students to explore class materials from different angles; help teach subjects where students could not feasibly gain real-world first-hand experience (e.g. Geography); enhance collaboration between students and teachers as well as among students; foster student creativity and imagination; help students take control of their learning at their own pace and on their own path, and create an authentic learning environment suitable to various learning styles [4, 5].

Most schools around the world take their students on educational trips or excursions to educative or cultural heritage places. Generally, the information about those places is provided in very limited pamphlets or by hiring a special person to guide the students, which cannot always be afforded by the school. Considering the current technology and the fact that nowadays most students own a mobile phone, a free and accessible way to create and provide more information is needed.

To the best of our knowledge, only a few researchers have addressed this need considering the currently available technology. Most of the existing AR frameworks and applications for mobile phones include proprietary and commercial engines [6]. However, none of them provides insights into their functionality or a way to customise the application to a specific purpose. In addition, only some of them allow the creation of new content. Furthermore, the available systems require an active internet connection during the tour, restricting eligible places to deploy such systems.

The inclusion of technology in the classroom has never been more feasible. In this context, we present ARPOT, an open-source, free, easy to use, and internet-free location-based AR platform for educational purposes. By using ARPOT's web application, the teachers are able to easily create data about a particular educative place and, with ARPOT's mobile application, students can use their own smartphone to visualise the AR content created by their teachers during the tour (see figure 1).

Results from the conducted study confirm that ARPOT is a very useful tool for teachers to create AR content about any educative outdoor place.

Furthermore, as [7] suggests, the use of innovative technologies improve the students' learning skills by providing a more motivating and engaging experience.

The rest of the paper is organised as follows: in the next section, the related work about AR platforms and applications for outdoor teaching is presented. The following section introduces the platform, the actors involved, and the activities they can perform. It also includes the description of the platform's main components: the web and the mobile applications. The section "Case studies" presents two different case studies designed to test the system; in the first one, the students use ARPOT's first prototype and visit the wetlands of Villa del Mar, Argentina; in the second one, the students test an improved version of ARPOT in the campus of our university. Finally, the discussion and conclusions for this work and an outline of the future work are presented.

2 Related Work

The research community is constantly working on the inclusion of AR in education [8–11], not only into the classroom but also into field trips. AR provides an opportunity for both learners and teachers to engage with the educative process in a very innovative way. According to teachers' opinion, learning improves when students are interested, creative and inspired [7]. Furthermore, pedagogy is paying much attention to learner's creativity and productivity.

Mobile AR has been studied for more than a decade. Henrysson et al. [12] and Pence et al. [13] outline a broad vision and discuss various possible applications. Wagner et al. [14] consider the challenges, strategies, and limitations to overcome while building mobile AR systems.

In this context, the literature presents some AR mobile applications for teaching outdoors, but only for very specific and particular contents. Chiang et al. [15] presents an augmented reality-based mobile learning system for conducting inquiry-based learning activities with students between 9 and 10 years old. These activities were developed following a five-step design methodology (ask, investigate, create, share, and reflect) and the experiment was conducted using a natural science unit on aquatic animal and plants. The proposed system relies on the internet for most of the steps. A more recent platform for creating AR content is Metaverse [1]. This platform allows users to create and share AR content and, based on the information presented on their web page, it is being used in many educational institutions. However, Metaverse does require an active internet connection. For this reason, it is not suitable for outdoor teaching in places with no wifi or mobile internet connection. Chou et al. [16] conducts an experiment on their university campus to evaluate the exploration of the campus via an AR mobile application based on wifi or 3G connection. They report a significant gain in motivation, attention or satisfaction by the students. In general, researches regarding the usage of AR in education confirm the benefits of this technology to the motivation and engagement of students during learning activities [17, 18, 9].

[1] https://gometa.io/

3 ARPOT Workflow and Components

ARPOT is a platform to provide augmented information about different real world surrounding Points of Interest (POIs) in real time. There are different actors involved in the usage of the platform and each one is able to perform different activities. Moreover, the platform consists of components designed specifically for each actor and its activities (A video showing ARPOT's functionality can be found at [2].

3.1 System Actors and Activities

Two actors are involved in the use of ARPOT: the teacher who creates the tour and the student who, along with the teacher, experiences the tour. Within the use of our system, there are three stages whose responsibilities go from teacher to student. For each actor and stage, there are activities that must be executed. Figure 2 presents the workflow of ARPOT and each stage is detailed next.

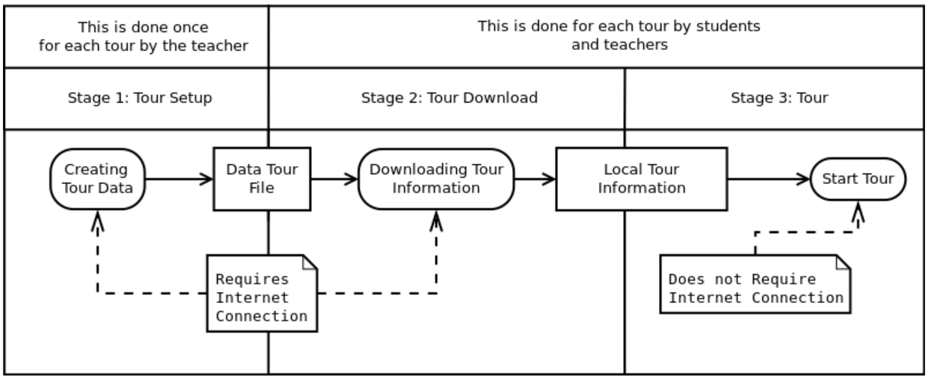

Fig. 2: The ARPOT Platform workflow is represented in this diagram. We identify three stages and two actors. Only the first two stages require an internet connection.

Stage 1: Tour Setup The tour setup focuses on the creation of a file with data for a particular tour. It is meant to be used by the teacher who wants to assemble a tour in a particular educative place. However, this is not restricted only to teachers; for example, the guides of an educative place may want to create a data file to assist them with more information about a particular tour. In this stage, the teacher must use the web application to create the data file that should be used later by the students. The web application was successfully tested in major web browsers, namely Chrome, Microsoft Edge, Microsoft IE, and Mozilla Firefox. The web application is currently available at [3].

[2] https://vimeo.com/290800417
[3] http://vyglab.cs.uns.edu.ar/arpot/index.html

Stage 2: Tour Download Once the students have the data file downloaded on their smartphones, they can download all the tour information by using the mobile application. The mobile application automatically detects all the data files with ARPOT extension on the phone and asks the student to select the data to be downloaded.

One of the main objectives of ARPOT is that no internet connection is required to use the mobile application in the field. For this reason, the mobile application downloads all the information once and stores that information in the phone's local memory. This stage also requires internet connection, but not a web browser. The mobile application is responsible for downloading the required information. Once this stage is completed, the students will be able to access all that information in a transparent way without requiring an internet connection.

Stage 3: Tour With the data already downloaded and stored in the phone's local memory, the students are now ready to travel to the selected educative place and use the mobile application. The mobile application is able to display POIs from the students' surrounding on the smartphone's screen. Specifically, the POIs are drawn based on the phone's orientation and position.

The development of a mobile AR application involves some challenges. In order to augment the image captured by the phone's camera with virtual information about the surrounding POIs, location-based calculations regarding the GPS location must be performed. Furthermore, an efficient and reliable technique for calculating the distance between any two positions is required. The distance and orientation between the student's current position and all the POIs' position should be calculated in real-time. On the other hand, the application must deal with many phone's sensors in order to determine the orientation and position of the phone. Finally, the angle of view of the phone's camera must be calculated in order to display the virtual objects on the respective position of the camera view on the screen.

The mobile application was developed by using Unity3d [4], a very popular and free game engine. Unity3d allows the developer to export applications to many different operating systems in a simple manner, including Android. In addition, Unity3d contains integrated tools to access most of the phone's sensors, which avoid the use of other external libraries.

By using this application, the students are able to view all the data generated by the web application, consisting of several POIs and their respective information. The students are not only able to see where these POIs are in terms of location and distance, but they are also able to see all the information associated to each particular POI (text, images, videos, etc.).

4 Case Studies

In order to test the usability and the performance of ARPOT, two case studies were carried out. First, teachers and researchers from the Department of

[4] https://unity3d.com

Geography and Tourism created a dataset of POIs about the Wetland of Villa del Mar and 240 students of different educational levels (160 students aged between 14 and 15 years –93 males and 67 females– and 80 students aged between 9 and 11 years –49 males and 31 females–) took the tour and used our mobile application. This location and these students were selected in the context of a pre-planned trip to Villa del Mar for students from the nearby schools, organised by the researchers of the Department of Geography and Tourism. Then, based on this first experience, ARPOT was improved and a second case study was planned, where 12 new students used our platform on the campus of our university. Both case studies are detailed next.

4.1 Case Study 1: Wetland of Villa del Mar

The coastline of Villa del Mar, Buenos Aires, Argentina, presents a diversity of landscapes resulting from the relationship between the elements of nature and the constructions that society performs. In this area, there are environments valued by their ecological functions and unique landscape; such is the case of the coastal wetlands of Villa del Mar. Therefore, acquiring knowledge and valuation of these local environments through formal and non-formal educational proposals encourages learning and awareness of their conservation. Every year, many students from nearby schools visit this place to learn more about its ecosystem.

In order to test the platform, teachers and researchers from the Department of Geography and Tourism used the web application to create a dataset with several points of interest about the wetland of Villa del Mar. After the dataset creation, the teacher downloaded the data file and sent it to the students via email. Every student then downloaded the data file and opened it with the mobile application. The mobile application automatically detects the data file and start downloading the corresponding content. This download process is performed just once, so no internet connection is required in the future for the same dataset. Therefore, the students performed this procedure at home with a regular internet connection. Finally, all the students arrived at the tour with the mobile application installed on their phones and with the tour's data already downloaded.

Villa del Mar was visited in October 2017 and each group was able to use the application to observe animal and plant species (see figure 3). The activity included four observation sites: Rocas Beach, the Municipal Beach, FRAAM (Foundation for the Reception and Assistance of Marine Animals) and an interpretive trail related to the wetland. After the visit, the students returned to the classroom to work on the gathered information, emphasising those aspects or problems of interest.

4.2 Case Study 2: University Campus

Every year, more than 4000 new students arrive on the campus of our university. The campus is growing each year with the addition of new departments, faculties, and classrooms; however, signs and maps are widely dispersed and very

Fig. 3: Using the mobile application. (Left) Student close to the location of the POI that represents "Balneario Municipal Villa del Mar". (Right) Information presented after tapping on the "Gaviota Cangrejera" POI icon.

confusing. Those new students usually get confused with colours representing the buildings, the campus division into sectors, and some incorrectly marked roads.

Generally, the new students get lost, arriving late for classes and losing precious time and energy. For this reason, this case study presents the use of ARPOT for the creation of a dataset containing all the relevant information for students, especially new ones. This information contains POIs with the location of the classrooms, the departments, the buffet, the ATM, the bus stop, among others. In addition, every POI also contains pictures to help students to identify the place.

A group of 12 new university students between 17 and 18 years old was recruited to perform a tour around specific locations of the campus. Half of them used ARPOT mobile application, and the other half only used the available physical signs around the campus.

The students started at the campus' entrance and they were asked to go to a number of places in a specific order. First, they were asked to go to a particular classroom, then to the buffet, followed by another particular classroom, followed by the Department of Computer Science and Engineering, and finally to the bus stop. Figure 1 shows a student looking for the buffet POI. The student can tap on any POI icon in order to get more information about it.

5 Discussion

Regarding Case Study 1, back in the classroom, the students were informally interviewed about the experience and about what they have learned. Many reported that the experience using ARPOT was more engaging and that they were very motivated to explore and learn about the place, the flora, and the fauna. They also reported that they could remember the information about most POIs because they were encouraged to physically reach them. Since the POIs' physical location represents a memory cue related to spatial cognition learning, walking through the POI helped the students to remember more information about such POIs. Even though in traditional trips the POIs are also associated with physical locations, the students are not encouraged to find and reach them, thus reducing their motivation.

Some POIs for plants or animals were intentionally placed where the actual plant or animal usually is. This was really surprising for many students because they could see a connection between the mobile application and the real world. For example, when the students approached the location where the mobile application indicated that there were crabs, they found actual crabs in the real physical location (see figure 4).

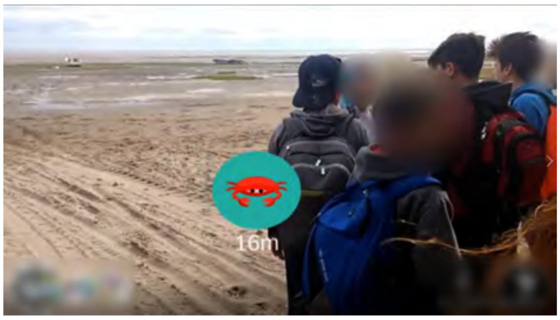

Fig. 4: POI indicating an area where actual crabs are expected to be found.

Regarding Case Study 2, the students who did not use the ARPOT reported that it was extremely hard to find the specified places. The existing signs around the campus are not very clear and the students needed to ask for directions or started searching the Internet for information. Four students mentioned that it would have been impossible for them to find some of the places if they had not asked for directions. The other students agreed with this.

The students who used the ARPOT mobile application reported that they could find each location very easily and that the general experience was motivating and fun. They mentioned that the inclusion of the buildings' facade pictures was really helpful. When they were walking from one location to another, some of the students were learning more about the surrounding places by looking at all the available information in the application.

6 Conclusions

ARPOT is an AR platform for outdoor teaching which provides a powerful tool for educators by helping them to create motivating and engaging experiences for their students. Considerable progress has been made regarding the inclusion of

AR technology in everyday education but many AR frameworks require a user with technical skills [6].

We created a platform so that people without a technical background can create educative AR tours. In addition, in contrast to most location-based AR systems for outdoors, ARPOT does not require an internet connection while the students use the mobile application in the tour. This is a novel and necessary feature because, for example in Argentina, most educative outdoor places are far away from internet coverage zones.

The present work has shown that ARPOT allows students to be protagonists of the teaching and learning process, interact with the elements that surround them, and visualise their closest environment from different perspectives. They become active participants by obtaining information that deepens on the knowledge of the complex social reality, thus contributing to the learning-by-discovery process. This set of tools presents an innovative potential to carry out educational practices that consider the exploration, the exchange of experiences and the active participation of students for the joint construction of knowledge. In addition, it is important to mention that thanks to the guidance and advice of the teachers, the students recognised the elements of the physical and natural environment, as well as the most significant problems of the addressed sector. This contributes to the understanding of complex geographic processes.

References

1. Jean Lave and Etienne Wenger. *Situated Learning. Legitimate Peripheral Participation.* Cambridge University Press, 1991.
2. Dee Vyas. Increasing student engagement using augmented reality. *The Journal of Educational Innovation, Partnership and Change*, 1(2), 2015.
3. Steve Chi-Yin Yuen, Gallayanee Yaoyuneyong, and Erik Johnson. Augmented reality: An overview and five directions for ar in education. *Journal of Educational Technology Development and Exchange (JETDE)*, 4(1):119–140, 2011.
4. Neven A.M. El Sayed, Hala H. Zayed, and Mohamed I. Sharawy. Arsc: Augmented reality student card. *Computers & Education*, 56(4):1045 – 1061, 2011.
5. Lucinda Kerawalla, Rosemary Luckin, Simon Seljeflot, and Adrian Woolard. "making it real": exploring the potential of augmented reality for teaching primary school science. *Virtual Reality*, 10(3):163–174, Dec 2006.
6. Teemu H. Laine. Mobile educational augmented reality games: A systematic literature review and two case studies. *Computers*, 7(1), 2018.
7. John Sener. In search of student-generated content in online education. *e-mentor*, 4(21):90–94, 2007. URL http://www.e-mentor.edu.pl/artykul/index/numer/21/id/467.
8. Kangdon Lee. Augmented reality in education and training. *TechTrends*, 56(2):13–21, March 2012.
9. Iulian Radu. Augmented reality in education: a meta-review and cross-media analysis. *Personal and Ubiquitous Computing*, 18(6):1533–1543, Aug 2014.
10. Fatih Saltan and Ömer Arslan. The use of augmented reality in formal education: A scoping review. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(2):503–520, 2017.

11. Hsin-Kai Wu, Silvia Wen-Yu Lee, Hsin-Yi Chang, and Jyh-Chong Liang. Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, 62:41 – 49, 2013.
12. Anders Henrysson and Mark Ollila. Umar: Ubiquitous mobile augmented reality. In *Proceedings of the 3rd International Conference on Mobile and Ubiquitous Multimedia*, MUM '04, pages 41–45, New York, NY, USA, 2004. ACM.
13. Harry E. Pence. Smartphones, smart objects, and augmented reality. *The Reference Librarian*, 52(1-2):136–145, 2010.
14. D. Wagner and D. Schmalstieg. Making augmented reality practical on mobile phones, part 1. *IEEE Computer Graphics and Applications*, 29:12–15, 05 2009.
15. Tosti H. C. Chiang, Stephen J. H. Yang, and Gwo-Jen Hwang. An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. *Journal of Educational Technology & Society*, 17(4):352–365, 2014. URL http://www.jstor.org/stable/jeductechsoci.17.4.352.
16. Te-Lien Chou and Lih-Juan Chanlin. Location-based learning through augmented reality. *Journal of Educational Computing Research*, 51(3):355–368, 2014.
17. M. Bower, C. Howe, N. McCredie, A. Robinson, and D. Grover. Augmented reality in education – cases, places, and potentials. In *2013 IEEE 63rd Annual Conference International Council for Education Media (ICEM)*, pages 1–11, Oct 2013.
18. Amy M. Kamarainen, Shari Metcalf, Tina Grotzer, Allison Browne, Diana Mazzuca, M. Shane Tutwiler, and Chris Dede. Ecomobile: Integrating augmented reality and probeware with environmental education field trips. *Computers & Education*, 68:545 – 556, 2013.