Educational Location-Based Augmented Reality Applications for Indoor Spaces: Creating the Application “Exploring the Aquarium of Kastoria”

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***Abstract*—Location-based Augmented Reality (AR) is a type of markerless AR technology where content is activated when a user reaches a specific location. This type of AR is currently used in many fields, such as tourism, recreational games, marketing, education, and initiatives that combine these purposes. Location-based AR applications typically rely on the mobile device’s Global Positioning System (GPS) sensor to report the user’s location. In indoor spaces, however, the GPS signals are either absent or weak, and tracking the users’ position requires alternative methods. This paper aims to present an educational location-based application for an indoor aquarium. The application was created to inform school students and visitors about the fish and other freshwater organisms exhibited in this aquarium. The paper also aims to present an affordable process for developing location-based AR educational applications for indoor spaces (e.g., museums, schools, etc.). This process does not require programming expertise or special equipment; therefore, it can be followed by all educators.**

Keywords—Augmented Reality; Location-Based Augmented Reality; Museum Education.

I. Introduction

Augmented Reality (AR) is a technology that has existed for many years. According to the literature, the first AR technology, an AR head-mounted display, was developed in 1968 at Harvard by a scientist called Ivan Sutherland. Since then, many initiatives contributed to the growth of AR [1]. AR, however, gained significant popularity when AR mobile applications appeared, and AR could be experienced using devices such as smartphones and tablets. Mobile augmented reality has experienced explosive growth over the last decade [2].

Augmented reality is currently used in many academic and commercial fields, such as tourism, marketing, entertainment, and education. It can also be used to fulfill more than one purpose. For example, an augmented reality application can be used to promote destinations and monuments by educating and entertaining visitors at the same time.

On the other hand, education is a sector where many AR innovations have been introduced. By exploring the literature, one can find a wide variety of AR applications designed for all levels of education. More specifically, there are numerous AR applications designed for primary (e.g., [3]–[5]), secondary education (e.g., [6], [7]), as well as higher education [8]. AR has also been used for a wide range of subjects, as it can be seen in a recent literature review [9].

Quite a few categorizations have been presented throughout the evolution of AR. One broadly known taxonomy concerns the way in which the AR experience is triggered. Marker-based AR, also referred to as image-based AR, relies on visual markers, such as Quick Response (QR) codes, printed images, and real-world objects 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.

Location-based Augmented Reality (LBAR) applications (or location-aware AR) 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.

However, location-based AR is limited in education regardless of its potential for creating application-assisted tours in areas of educational interest (e.g., open museums, cultural heritage sites, and places of environmental interest). 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 Science, Technology, Engineering, and Mathematics (STEM) augmented reality applications in higher education [8] revealed the scarcity of markerless AR and location-based applications in the specific field. Furthermore, creating AR applications for indoor spaces (e.g., museums) remains a challenge since GPS sensors lack precision in such places or fail entirely. This paper aims to present an indoor location-based AR application and the methodology and tools used for developing the application. The application aims to inform the visitors of an aquarium about the fish exhibited in the aquarium’s tanks. Furthermore, the paper also aims to present the tools and process for creating location-based AR for indoor spaces using an open-source authoring tool, which many educators can use since it does not require advanced technical knowledge.

In Section II, the available technologies for creating location-based AR applications will be presented. For this project, Taleblazer was chosen since it is an open-source and reliable solution. Taleblazer and its mechanism for creating such applications will also be explained briefly in this section. In Section III, a gamified location-based AR application for an indoor aquarium will be presented, and in Section IV, insights obtained from students who experienced the application during school visits to the aquarium will be discussed. The paper concludes in Section V.

II. CREATING LOCATION-BASED AR APPLICATIONS FOR INDOOR SPACES

A. *Exploring the available position tracking technologies for indoor spaces. Using beacons for location-based AR.*

There are a few ways to create AR applications that keep track of the user's position in an indoor environment and activate content when the user gets close to certain locations. One way to achieve this is by using an indoor positioning system. This system consists of electronic devices and special computer software for locating people or objects in settings where the GPS signal is weak or absent. Multiple indoor tracking systems technologies exist, including radio-based, optical, magnetic, and acoustic technologies. One hardware solution that is commonly supported by authoring software used for building location-based AR for indoor spaces is the iBeacon technology. An iBeacon is a Bluetooth low-energy device that only sends a signal in a specific format [10]. Beacons regularly broadcast packets in the iBeacon format. iBeacon packets contain the beacon's identifying information and the power level at which the beacon is transmitting. The iOS and Android operating systems provide libraries for determining three proximity levels based on signal strength: immediate, near, and far. Multiple precision levels can indicate the user's position and support different application (or game) mechanics.

Some museums utilize beacons and AR to replace audio tours that rely on special equipment and provide visitors with a better experience by relying on their mobile devices. Beacons can transmit information about a user's location in the museum. If the user's location is known, then static or dynamic information about the exhibits (which can be in multimedia form) can be delivered.

The National Slate Museum in England developed the Slate Museum| Amgueddfa Lechi app in 2014 and applied beacon technology to the museum so that visitors can use the guiding app [11]. The researchers of [12] used AR and beacons to develop a museum tour guide application. More specifically, the Chang Gung University Digital Media Lab combined AR and beacon technology to build the Formosa Plastic Group Museum's guiding system. The tour guide application provides an information-guiding service and various interactive education and entertainment functions. Furthermore, a recent study [13] explored Bluetooth beacon use cases in teaching and learning. Among the 33 reviewed studies, two combined AR with beacon technology in an educational setting. More specifically, Jurkovičová et al. [14] created an AR application that utilizes beacon technology to guide students around a learning space using complementary overlaid visual information displayed on their own devices, and Karlsson et al. used beacon–AR synergy to develop an educational quest game called ArQuest [15].

Although the use of beacons can solve the problem of the absence of a GPS signal in indoor spaces for AR applications by tracking the user's position, it must be said that beacons come with a cost. The average price for a single beacon is around $25, and in spaces such as museums with many exhibits, many beacons may be needed. In the next section, a way for developing location-based AR for indoor spaces without extra equipment will be presented.

Another concern when building location-based AR applications for indoor spaces is the authoring tools. While there are many solutions for developing AR applications, most of them require advanced programming knowledge. Many applications have been built using development tools, such as ARCore, ARKit, WikiTude, and Vuforia, but these tools are intended for experienced programmers. On the other hand, there are tools such as Taleblazer [16], Metaverse Studio [17], and ARIS [18] that require little or no programming experience and are suitable for most educators who are interested in building AR experiences for their classes. In previous studies, we explored the capabilities of Metaverse studio, Taleblazer, and ARIS to detect the pros and cons of these online authoring software packages for educators without particular expertise in software development [19][20]. The comparative analysis in [19] revealed that, while the application development with Taleblazer is not as simple as with Metaverse Studio, the advantages that Taleblazer provides in developing location-based AR apps are greater when compared to those provided by Metaverse Studio. Therefore, it is worth it for educators to make the extra effort to get acquainted with the Taleblazer programming environment.

TaleBlazer was developed by the "Scheller Teacher Education Program (STEP)" of the Massachusetts Institute of Technology (MIT). Taleblazer has a visual block-based programming environment similar to Scratch [21], another famous product of MIT.

Regarding indoor location-based applications, both Metaverse Studio and Taleblazer support the use of iBeacons, and Taleblazer has detailed documentation on how to proceed with such a task. Furthermore, Taleblazer provides creators with an additional way to develop such applications, which is also cost-effective since it does not require special devices. This option will be discussed in the following subsection.

B. *Using Taleblazer and password-protected Agents for building location-based AR applications.*

The Taleblazer development environment relies on a visual block-based scripting language (Figure 1).

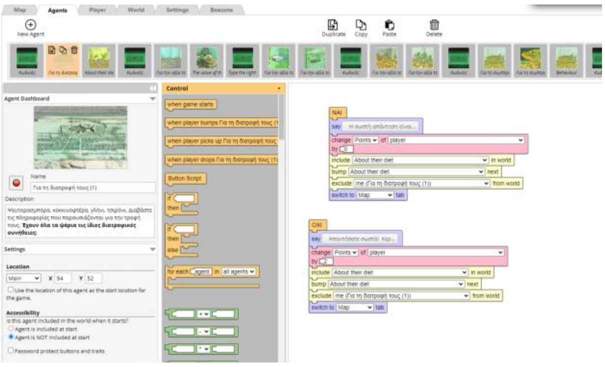

Figure 1. Taleblazer visual block-based scripting language environment.

To program a location-based learning application (e.g., game), the educator must be (or willing to get) acquainted with a visual block-based programming language that is very similar to Scratch, another known product of MIT as mentioned in the previous section. The visual block-based programming environment of Taleblazer is suitable for people with no prior knowledge of programming. Visual block-based programming environments are extensively used for introduction to programming and computational thinking and are also ideal for young kids.

The basic elements of the Taleblazer environment are “Regions” and “Agents”. Regions are the physical areas on a map where the game takes place. The first thing that a designer must do is to determine the region of the game on a digital map using a selection tool. After the region is set, “Agents” can be introduced. Agents are digital content associated with a GPS location and activated when a learner “bumps” into this location.

Taleblazer utilizes the Google Map Application Programming Interface (API) to guide user navigation. Furthermore, Taleblazer provides the ability to use custom maps besides the Google dynamic map. This means that creators can create their own maps using image editing and graphic design tools, and applications can be experienced on these custom maps as long as they are matched appropriately with the physical locations. This option allows designers to create applications that do not require an active internet connection during gameplay. Custom maps are also necessary when developing indoor applications since images of the interior spaces will have to be created (Figure 2).

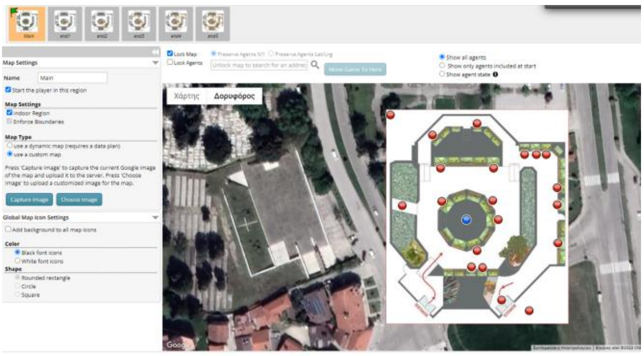

Figure 2. Snapshot from the Taleblazer development environment. Inserting location points (red dots) on a custom map and associating these points (Agents) with multimedia content.

Taleblazer also has two settings called “Autobump” and “Tap to bump”. When the user comes close enough to the target GPS locations defined in the application scenario, a Taleblazer agent is activated. According to the Taleblazer terminology, the player is said to have ‘bumped’ into the Agent. In Taleblazer, an agent is activated either automatically (Autobump) or by tapping on the red dot of the Agent on the map (tap to bump). In the absence of position tracking, the “tap to bump” option can be used together with password-protected agents. This feature is provided by Taleblazer and is well explained in its software documentation.

By activating the “tap to bump – regardless of the player location” option in the ‘bump settings’ and using password-protected agents, an indoor location-based application can be created without position-tracking devices. Agents are placed on the custom map, and passwords are associated with these agents. The passwords must be placed close to the physical location of the Agents in the indoor physical environment, and the application designer can think of various ways to achieve this (e.g., signs, stickers, etc.). The player will have to tap on the appropriate icon (Agent) on the application map and then insert the password found close to the target location to activate the digital content. This way, it is guaranteed that the player has reached the required location in the indoor region.

III. The Application “Exploring the Aquarium of Kastoria”

The application is a joint effort between the Center for Education for the Environment and Sustainability of Kastoria and the Digital Media and Strategic Communication Lab (DMSClab) of the Communication and Digital Media Department, University of Western Macedonia, Greece. These two entities are in close collaboration to implement research and education projects related to new technologies in education. Every school year, a large number of K-12 students visit the Center for Education for the Environment and Sustainability of Kastoria to attend one of its educational programs. The Center has also adopted augmented reality technologies in some programs to enhance the educational experience.

Kastoria is a city in the province of Western Macedonia, Greece, a city near a lake named Orestiada. The larger part of the city is a peninsula that is literally surrounded by the lake. The aquarium of Kastoria hosts fish and other freshwater organisms of Greece that are either indigenous, endemic, or foreign. Most of the exhibited fish species in the aquarium have been living for centuries in the lakes and rivers of Greece, but there are also species that have been imported from other countries at some point. It is the largest freshwater aquarium in the Balkans, and in recent years has become one of the main attractions of the city of Kastoria. The aquarium is visited every year by a large number of tourists as well as students who visit the aquarium as part of organized school trips (Figure 3).

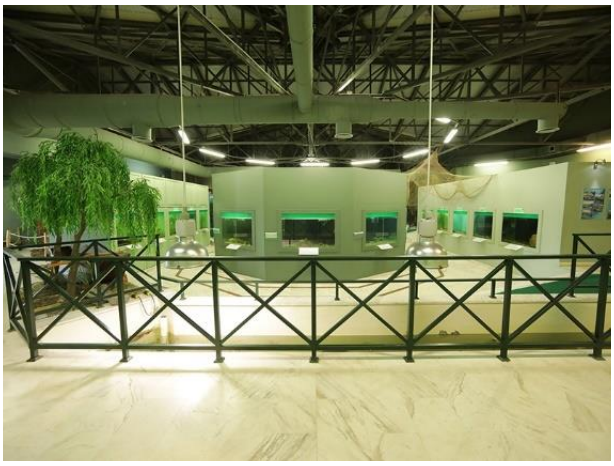

Figure 3. A picture from the interior space of the Aquarium of Kastoria.

The “Exploring the Aquarium of Kastoria” application is accessible to all aquarium visitors. The application is currently in the Greek language only, and there has been a translation of several screenshots for the purposes of this paper. In Figure 4, one can see the initial screen of the application.

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Figure 4. The initial screen of the application.

Seeking to exploit the advantages offered by location-aware AR technologies, the augmented reality digital application "Exploring the Aquarium of Kastoria" was designed with the following objectives in mind:

- To provide an alternative method that will mobilize the students' interest and strengthen their active participation during an educational program.
- To strengthen the experience of the educational activity through continuous observation and interaction with the real world (aquarium exhibits) and the digital elements of the AR mobile application.
- To evoke positive feelings usually present when students participate in games that encourage cooperation and are supported using their favorite means of entertainment and communication devices (smartphones and tablets).
- To utilize and further develop the students' digital literacy.
- To provide students with attractive means of obtaining information about the fish exhibited in the aquarium. The students can also visit the aquarium after a school trip, alone or with their family or friends, and experience the AR application at their own time and pace.

The application aims to inform users about the following aspects:

- What the fish eat
- Their value in environmental sustainability
- Their behaviour
- The polymorphism of their species
- Facts regarding the endemicity and migration of fish
- The threats to their existence.

The application has been developed using Taleblazer and password-protected agents. First, a custom map of the interior area of the aquarium was created using an image editing program. Adobe Photoshop was used in our case, but other open-source or free image editing programs can be used (e.g., Gimp, Photopea, etc). This custom map was then inserted in the Taleblazer development environment, and location points were inserted on this map (Agents). The location points were placed at several fish tanks (21 locations). The application users get oriented in the beginning by looking at the map and the first location to be reached (depicted as a red dot in Figure 5).

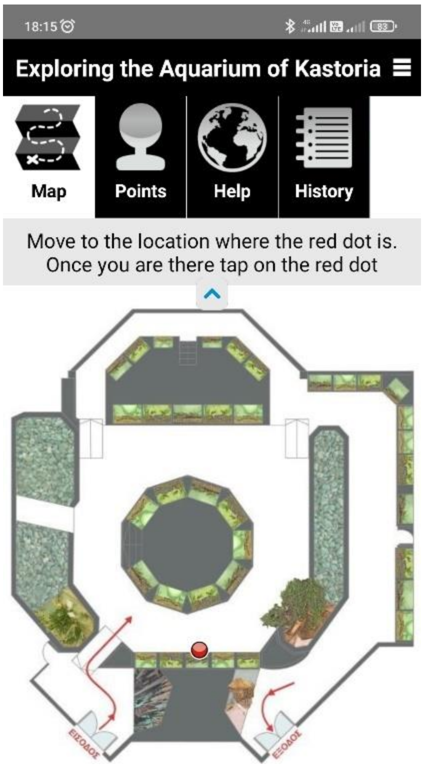

Figure 5. A custom map of the aquarium. The red dot is the first point that the application user must visit.

After the users get acquainted with their position and the map, they are ready to embark on the tour. The tour is not sequential, meaning that the users are not prompted to visit the tanks one by one and in the order that they are exhibited in the aquarium. The visitors are led to move in a seemingly random order inside the aquarium with the task to observe, think, answer questions regarding the fish, and collect points when these questions are answered correctly. The next location is always depicted with a red dot. The users would have to move to the next location on the map and tap the red dot when they are in front of the right tank. A message then pops up on their screen asking them about the correct code (Figure 6). Signs with number codes have been placed above each tank. The signs can be seen in Figure 7.

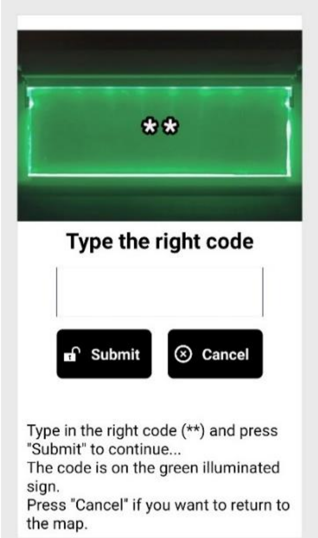

Figure 6. The user is prompted to enter the correct code.

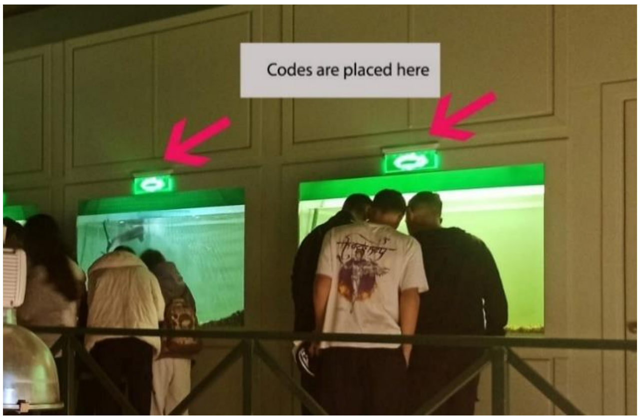

Figure 7- Signs with codes are placed above each tank.

Giving the correct code means that users are at the right location, observing the fish intended by the application. A message confirms whether the user is in the correct location. After this message, the users are asked to answer two questions regarding the fish exhibited in the tank before them (e.g., Figures 8 and 9).

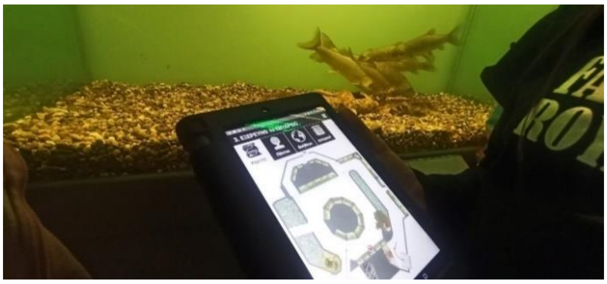

Figure 8. An application snapshot.

Figure 9. Questions are posed to the users regarding the fish they see in the tank before them.

The answers to the questions can be, in most cases, obtained by reading the information on the signs that exist underneath each tank. The signs contain the name of the fish and information about them. The application also gives additional information. Points are awarded every time the user answers correctly. At any stage of the game, the users can see the points they have collected by visiting the points tab (Figure 10).

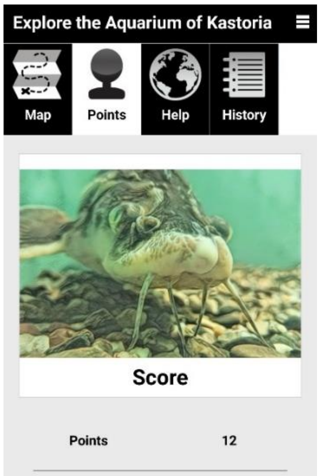

Figure 10. Points are awarded for correct answers.

The application also has sound. The information and the questions are also provided by a recorded human voice besides the application text. Visitors and students in the aquarium are advised to use headphones or keep the mobile device at low volume and next to their ears to listen to the application sound without disrupting other visitors.

IV. Insights obtained from application use

Initially, the application was tested by all four educators who work at the Center for Education for the Environment and Sustainability of Kastoria. The educators did not experience any problems while using the application.

Furthermore, the application was experienced by more than 100 students. Students were asked to experience the application in small groups after a small demonstration on how to use the application. Almost all students had not previously experienced a location-based AR application for indoor spaces. The students were left alone to navigate the aquarium while the Center's educators observed their behaviour. While younger primary school students (ages 6 to 9) needed some time to get oriented in the aquarium by using the application map, older students (ages 10 to 17) had no problems navigating in the aquarium using the application. Furthermore, it was obvious to the observers that the students were excited with this gamified method of exploring an aquarium and learning about its exhibits. Many students also expressed positive opinions about the novelty of the application to their peers and teachers.

V. Conclusions

This paper concerns location-based AR applications for indoor spaces and how such applications can be developed. While AR is widely used in education, location-based AR is limited and mainly concerns open spaces (e.g., city tours, cultural heritage sites, etc.). Location-based AR use cases for interior spaces where the GPS signal is either weak or totally absent are even fewer.

Position-tracking devices, such as iBeacons, are encountered in literature as a way to implement location-based AR for interior spaces. However, these devices come with a cost. Moreover, most AR applications encountered in the literature rely on development tools that require advanced programming expertise. This paper presents an affordable way for creating educational location-based AR for interior spaces without the need for special devices, using an open-source software platform (Taleblazer), which is suitable for educators without previous programming experience. The paper also presents an educational application for an aquarium developed using this methodology to provide ideas and guidance for educators who wish to create similar applications (or games). Preliminary insights obtained from observing students who used the application are very encouraging. A limitation of this research effort is that a systematic evaluation using a large sample of students has not been carried out, and that is something that the research team intends to do in the future.

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