An Interactive Application Framework for Natural Parks using Serious Location-based Games with Augmented Reality

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Abstract: Park visitors and tourists, in general, seek new experiences, leading to a growing search for ways to create more memorable experiences. Some technological solutions, such as Augmented Reality, have proved that they can be useful to create more immersive and interactive experiences, both in entertainment and education. An application with Augmented Reality, using location-based services in a gamified way, can create pleasant and entertaining outdoor experiences without losing its pedagogical ability, making it a promising fit for a nature park. We propose a conceptual framework for creating these mobile applications for nature parks. From which, a mobile application was prototyped with location-based services and augmented reality interactive experiences, with the purpose of disseminating scientific knowledge about the fauna and flora of a nature park. Gaming elements are also introduced in the application's design to try and improve the engagement and involvement in the various activities of the application and its contents. User tests were performed during the development of the prototype and with the final version. The results allow us to conclude that this type of applications can improve the visitors' experience while at the same time, improve the dissemination of scientific knowledge.

1 INTRODUCTION

Interactive environments, such as mobile applications and games, offer new ways of providing different experiences in several areas, being tourism and science communication some examples. Visitors, in general, seek involvement in new experiences, leading to a growing search for ways to innovate in the way visitors experience the places they visit (Pereira, 2016). Therefore, by taking advantage of new technologies, interactive experiences can be created as new ways to communicate science to the visitors of, for instance, museums and nature parks.

One way to do it is through games. Their versatility and potential to integrate pleasure, learning and reflection (Gee, 2006) is known. Furthermore, applying Augmented Reality (AR) elements, with location-based systems, in a gamified way, provides a bridge between the digital world and the physical world, giving pedagogical content, while still maintaining the epic experience a tourism visit should have. Because of this, games can be an asset in the creation of new experiences in natural environments, helping to promote natural heritage through Science Communication and environmental awareness (Santos et al., 2016).

We propose a framework for the development of an interactive mobile application for visitors of nature parks. To test the proposed concepts, we developed an application that interacts with the park environment through AR and location-based systems. Tests were conducted with potential users *in loco* to evaluate the application and verify if it enhances the visitor's experience.

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2 RELATED WORK

This section provides a brief overview on AR applications and game design for engaging experiences in Tourism and Education.

Brown and Chalmers (2003), point out that some of the pleasure in tourism comes with the exploration aspect of the experience. Therefore, maps and the application's guiding information should be enough so the visitor will not feel lost and, also, not too detailed, to encourage exploration.

AR is an excellent tool to introduce information about the physical world, interactively and helpfully, as can be seen in *Skin & Bones* (Marques and Costello, 2015). This application has an AR mode that allows the visitors of the Bone Hall at the Smithsonian's National Museum of Natural History, to see the exhibition's skeletons with a 3D representation of the animal's external anatomy and highlights the particularities of functional anatomy. The results from the user experience showed a unanimously positive reaction. Some participants stated that the (re)contextualization that the AR mode provided helped to understand better and retain the information (Marques and Costello, 2015).

Games have proved to be effective in motivating and engaging people with media content. Serious games are an effective and adaptative pedagogic tool which motivates and engages the learner in the educational context (Michael and Chen, 2006; Marsh, 2011). Hence, games can be an asset for science communication in museums, parks or other cultural touristic attractions, as they enable the creation of pleasant experiences, while still maintaining other priorities as its focus (Chess, 2014). These games can even be enriched with the introduction of new technologies such as location-based systems and AR.

Location-based games can be used as a way to make the player navigate between different landmarks, in an engaging way (Chess, 2014), which is essential for tourism-oriented applications.

The use of AR in these games is increasing as technology advances. The company *Niantic* is an example of this evolution. In games such as *Ingress Prime*, the famous *Pokemon Go* and *Father.IO*, there are specific real locations where the player must go, to get items or perform specific game-related tasks. Sometimes, these locations are points of cultural interest, historical landmarks and buildings of importance to the region. The location-based services are used to promote the exploration and interaction with the regions around the player. Also, when these location-based games that track and use the player's location in gameplay are combined with AR elements, they create immersive and entertaining games. Furthermore, AR offers effective and attractive ways to educate with the possibility to interact with the environment (Kysela and Štorková, 2015), while not retaining the user's full attention. These are all objectives to have when creating an application to promote outdoor interaction.

Developing an engaging game is a crucial challenge of game design (Söbke et al., 2017). Both Schell (2008) and Kiili et al. (2012) profess the importance of the state of "flow", in which the player is focused, interested, engaged and enjoying the experience. Both authors state that to put a player into a flow state, the activity in hand must have clear goals, no distractions, direct feedback, and must be continuously challenging. If the challenge is hard, the player will feel frustrated if it is too easy, the player will feel bored. Schell (2008) suggests that the challenges should be attached to the progression to combat those states of anxiety and boredom.

The best way to integrate gaming with teaching is by having a balance between fun and learning (Perrotta et al., 2013). The game design must relate the educational content with the gameplay by making the learning content integral to the game, rather than an add-on, as content-specific tasks work better when embedded in the fictional game context and rules/mechanics. The authors recommend to not separate non-contextualized game components, such as badges, scores or leader boards, from the fictional context and game mechanics. Lastly, Gunter and Kenny (2006) bring attention to the importance of focusing on context and educational goals. For these authors, serious games require the design to support "Cognitive Interactivity", as this model allows the game's pedagogic aspect to succeed in its knowledge dissemination objective.

3 INTERACTIVE NATURE PARK APP FRAMEWORK

A visit to a park has a few challenges associated. Visitors do not always have a good sense of orientation and may often feel lost, even if the park has signboards with directions. Some points of environmental interest may go unnoticed because they may not have information to explain why they are essential, or which animals and plant inhabit them. Other points of interest (POI) may have information but still going unnoticed because of it not being interactive.

A park may not have enough information or hold information that people do not feel like reading. Two main challenges can be translated from this: how can visitors know where they are at every instant in a park and how can they have a better experience that is not only fun but also informative.

A framework was developed to tackle these challenges. It consists of a set of guidelines for mobile apps to support and enrich the visit to a nature park. According to this framework, a mobile app for parks should contain the following items *i*: *i*(1) a map, *i*(2) GNSS (Global Navigation Satellite System) positioning, *i*(3) Points of Interest (POI), *i*(4) interactive information and *i*(5) contextualized serious games.

The park map *i*(1) should, in conjunction with the GNSS positioning *i*(2), allow visitors to locate themselves, showing them where to go. It should also present some POI that are geolocated, so the visitor can be informed of what will encounter on the way. If the park already has a map illustration that is used in signage, it is better to maintain the design to avoid inconsistencies and confusion for visitors.

The app should also include information about the POI *i*(3) available in the park and easily accessible for the users. This information should be interactive *i*(4) and about its biodiversity, acting as a support to the visit, enriching it in a non-intrusive way. Thus, its focus would mainly be in the real natural world surrounding the visitors, while still maintaining a pleasant and fun experience. To do this, the application must have a way to interact with the park environment. Location-based systems and AR allow expanding that interaction.

Contextualized serious games *i*(5) are recommended to promote a sense of exploration and awareness about the park and to create engagement. AR elements and location-based services can also be included in these games. They provide ways to unlock rewards, thus incorporating a sense of progression within the application. Moreover, the app should include a collection about the native species and information about them, to further engage the visitor in exploring the park's biodiversity. This can be accomplished by having individual activities throughout the park circuit with a common goal, which is achieved by unlocking and collecting digital collectable virtual cards, that can be seen in a joint collective board.

The final result must be an application easy to use by the general public and supported by most smartphone devices with a camera and GNSS positioning. Following this framework, a functional mobile application prototype was developed and is presented in the next section.

4 IMPLEMENTATION

A functional mobile application prototype was developed according to the framework guidelines listed in the previous section. The application aims to provide the visitors of nature parks, some information about its biodiversity, enriching their visit in a non-intrusive way. This prototype was developed specifically for the biologic park (Parque Biológico) of Gaia, Portugal, with an extensive area populated with numerous species of animals and plants living in a wild state. The park presents itself as having good potential for the creation of a touristic and educational location-based game.

4.1 Architecture

When starting the application, the first thing the user sees is the map and the icons of the POI, providing access to information about the activities and the park in general. These activities are available in specific locations within the park and can only be triggered and initiated when the user is physically located on those places. In each activity, the user can unlock and collect virtual representations of the park's species and information about them, through playing these activities. Those collectives can be seen in a joint collection board. Given their importance, the application's flow was designed in a way the user can access their information from any activity, as shown in Figure 1.

This paper describes one of the activities developed, *Birds of Prey AR*. Presently, the prototype is supported by all Android devices, running at least Android 4.4 (KitKat). The Unity 3D game engine was used to provide support for distinct devices. AR services were performed using Wikitude.

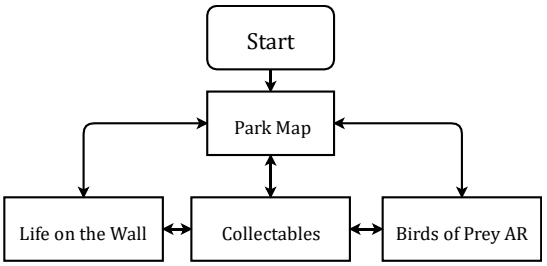

Figure 1: Application's main flow.

4.2 Map and Location-based System

The application starts with a stylized interactive map of the park (see Figure 2). It highlights the park's POI, and it is the same map used in the park's signs scattered along its circuit. Thus, using the same image avoids disconnecting the user from the park, and the app would not be disruptive.

A blue icon represents the user's location, making the user always able to locate oneself on the map an orange dashed line shows the path taken. This allows the visitor to be aware of which portion of the park's circuit has already been visited. This will encourage the user to return to the park to discover the POI not visited yet. The POI are represented on the map by small green circles with numbers or letters. By taping these icons, an animated pop-up reveals what they represent. The screen also has a help button and a button for direct access to the *Collectables.*

The prototype uses the device's GNSS coordinates to calculate the user position in the stylized map (Santos et al., 2017). Since it is an illustration that is not at scale, it is not possible to directly translate GNSS coordinates into map coordinates. To accurately calculate the user position in the map, real-life GNSS coordinates of strategically chosen points in the park were recorded to a JSON file that is loaded every time the application starts. All map paths were mapped through various points at close range, where each point on the map was paired to a real coordinate. An interpolation was made between the two nearest points of the user's GNSS position, to determine the user's position on the stylized map. The use of a JSON file allows to easily manage and update these points if, in the future, the park changes the circuit. Furthermore, it becomes easy to replicate the location-based system to different parks and circuits.

Figure 2: Park's stylized map, the user's path dashed line and a blue icon with field of view representing his location.

4.3 "Collectables"

The *Collectables* is a collection of illustrations of plants and animals with associated information. Each of them represents a species that can be found in the park. To unlock them, the user must first interact with those species in the AR activities. The unlocked species are represented in the collectables board with their image and scientific name (Figure 3).

When the user interacts with one of those unlocked species, it shows more information about it (see Figure 4). The user can always access each of the *Collectables* by interacting with the button representing it on the map scene. From here, the user has access to her/his collectable species and sees what species (s)he already discovered and how many are still yet to be discovered. The species not yet discovered are shown as a question mark.

Figure 3: Collectables scene with three discovered species.

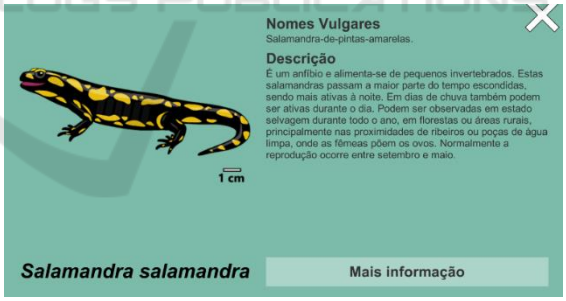

Figure 4: *Salamandra salamandra* species information.

4.4 "Birds of Prey AR"

The purpose of this mini-game is to engage the user to spot "augmented" birds of prey flying above her/him and correctly guess the species' name based on the birds' silhouette. This information can be accessed on the *Collectables*, after being unlocked.

In each game session, the player has 60 seconds to find "augmented birds" and correctly name them to accumulate the highest score possible. The score is determined by the answers given, if correct or not, the bird's difficulty and its distance to the user. The game

starts with a countdown, after which birds of prey will randomly spawn and fly around. When the player sees a bird must select it by tapping on the silhouette of that bird. Three buttons show the possible answers (see Figure 5). The player then selects the answer and a "correct" green mark will pop-up if the answer is correct, or a red cross if not. The score is also updated, and the best score is always recorded, which, according to Frattesi et al. (2011), encourages replayability, for more engagement.

When a bird is selected for the first time, it will be immediately unlocked and added to the collectables board. The player then can access the Collectables and view more information about the newly discovered bird. Accessing the *Collectables* in the middle of a game will pause the gameplay.

The game has an option to use "binoculars" that, when activated, will zoom in the game (as real binoculars), as can be observed in Figure 6. This in-game feature makes it easier to observe the differences between the birds' silhouettes. However, it becomes harder to follow the birds, as it will appear as if they move relatively faster in the screen, due to the narrower field of view. Green arrows indicators (see Figure 6) are shown in the screen's edge to guide the player to point the camera to where the off-screen birds are.

After 60 seconds of gameplay, the end game screen appears with the score the player achieved and the highest score. The player can then play again, access the *Collectables* or exit the mini-game.

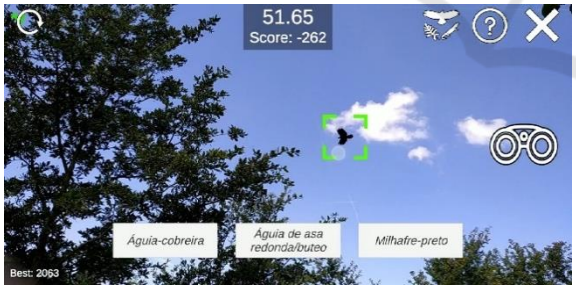

Figure 5: *Birds of Prey AR* with a selected bird.

Figure 6: *Birds of Prey AR* with the binoculars' view and green arrows indicators.

5 EVALUATION

The developed prototype was evaluated through user studies. Some of these tests were performed during the development activity to evaluate isolated parts of the application so they could be improved. This methodology uses the process of user-centred design, as according to Abras et al. (2004), where products can only be refined through feedback collected in an interactive iterative process involving users.

5.1 Preliminary Studies

User studies were done during the development activity, to evaluate the map design and the *Birds of Prey AR* mini-game indicators, so both could be improved. During the two tests, users experimented these prototype features on a smartphone and, after each part, answered a few questions from two questionnaires. Some observations were recorded on an observer form. A total of 34 volunteers participated in both tests.

The application's map test started with each participant being asked to point out the nearest point of interest, and then to rotate in that direction. The observer took notes if the user succeeded or not and helped the user in the case of failure. Finally, the user was asked about the meaning of the orange dashed line in the map, and the observer filled the answer in the form. Hereafter, participants filled a questionnaire about their experience. Ages were between 11 and 61 years old, ($\bar{x} = 34.97 \pm 15.14$), with 41.18% male and 58.82% female subjects.

Table 1 shows the results from the questionnaire, considering a 7-points Likert scale, ranging from "Strongly disagree" to "Strongly agree". The observation shows that 94.12% of the participants understood their orientation on the map and correctly oriented themselves. Given that, there were no changes in the icon representing the user location on the map. Also, 82.35% of the users associated the dashed line to the representation of the path taken by the user. The remaining 17.65%, associated the dashed line with the path to take. The users noticed at least one of the activities icons on the map (82.35%), and since they were visible enough to stand out, there was no need to redesign them. These results confirmed that the application's map design is an easy way for the users to locate and guide themselves through the park, and so, no changes were introduced.

The *Birds of Prey AR* usability test was conducted to evaluate the indicators designed to guide the player to virtual birds of prey in this mini-game, as well as the overall game experience. The indicators (green

arrows) purpose is to guide the player to the birds' location. They were created to reduce the player frustration and feeling of being lost when the player cannot find any birds. The users were asked to try two different versions of the same game, one with indicators and one without indicators. Each game version started after a countdown reaching zero. It then spawns the screen with birds of prey, being that the total number of birds spawned at every instant is 5. After spawning, these birds fly in circles around the player while always maintaining their starting height and distance.

In this preliminary test, the birds were scaled to their real-life size on which 1 scene unit equals to 1 meter in real life. They spawned at random position around the player at a minimum distance of 5 meters and a maximum distance of 10 meters with their spawn height ranging from 5 to 8 meters. There were five species of birds in the spawn pool, their wingspans ranging from 0.65 meters to 1.65 meters. When the user tapped on a bird, it disappeared, and another random bird would spawn.

The user had to touch the maximum number of birds in less than 60 seconds, per game session. The game's version order was randomized for each user to minimize the primacy and recency effect. During each version, every user comment was noted by the observer. The application also registered, for each version, the number of birds touched by the user. The test was done in an open area in the middle of the day to try to replicate the park's location where this activity would take place. After, the participants filled a questionnaire regarding demographics and their opinion about the experience.

Table 1: Results from the application's map test.

Question	Median	Q1	Q3
I use my smartphone very often	6	4	7
I am comfortable with navigation applications	5	3.25	6
It was easy to locate myself on the map	7	5.25	7

Table 2: "Birds of Prey AR" indicators test results.

Questions	Median	Q1	Q3
The game controls worked as expected	4	4	5
The game was fun	5	4	5
I liked the game visuals	5	4	5

Some of the questionnaire questions; used a modified Likert scale in text form, as follows: "Strongly Disagree", "Disagree", "No Opinion", "Agree" and "Strongly Agree", being valued from 1 to 5, respectively. The results are shown in Table 2.

The very positive results show that users found the game fun and liked its visuals. Most participants think the game is suitable for a young audience, being that more than half of the participants selected the age groups of "Less than 18" and "18-35". They tended to select their age group and lower. In the optional comment and suggestions section, two participants wrote that the game needed to show more birds and that a participant felt dizzy playing it because he had to rotate himself a lot so he could see more birds. Additionally, there were some comments about participants in the age group of 35+ years old feeling tired because they had their arms extended too high while playing.

Results show that 88.24% (30 out of the 34) of participants had a higher number of interactions with the virtual birds when using the indicators as opposed to not having the indicators.

There were instances where this difference was bigger than 50%. After normalizing the gathered data, the resulting information was that, when using the indicators, the participants had a higher number of interactions with birds, with an average increase of 21.82% ± 14.68%. This result led to the decision of using indicators in the *Birds of Prey AR*, as it was shown that the presence of indicators increases the number of interactions the user has with the birds.

Nonetheless, considering all results, comments and suggestions, some changes were introduced to the *Birds of Prey AR* mini-game. The minimum number of birds that are spawned at any given instance during the game was increased to 20%. The spawn height range was changed from 5 - 8 meters to 3.5 - 5.5 meters. The spawning algorithm was also changed from randomly spawning behind the player's field of view, to spawning near the edges of the player's field of view. Also, the flying direction goes through the player's field of view. These changes make the birds appear more often in front of the player, thus not requiring him to turn around to see a bird. Moreover, since they now appear at a lower height, the players can have their arms in a more comfortable position.

5.2 Usability Test at the Park

A final test was designed to evaluate the application usability *in loco*. It took place in the Biological Park of Gaia, Portugal, with a sample of 27 participants, who voluntarily walked over a specific path while using the application to try the activities. Each test had a duration of 20 minutes on average. Before starting it, the application settings and progression

would be cleared to ensure the most similar experience between the participants.

The test started at the park's entrance, where each participant was given a smartphone with the prototype already running. The participants were free to explore the application and were shown the *Collectables*, as seen in Figure 3. They were told that some of them were already unlocked and that the rest could be unlocked in the activities they would be performing. While walking the path to the mini-game *Birds of Prey AR*, it was explained what users could expect from the game and its rules.

The mini-game *Birds of Prey AR* took place at an open area, at the end of the established test path. After playing it, the test would reach the end and the participants would then fill a paper questionnaire. The observer also noted any relevant comments and suggestions pointed out by the participants.

The questionnaire had two parts, one with 16 questions about the users and their opinion about the application and the other with 10 questions from the System Usability Scale (SUS) (Sauro, 2011), to measure the application usability. There was also an optional comments and suggestions field, so the participants could freely share their opinions.

The participants' ages ranged from 14 to 79 years old ($\bar{x} = 42.15 \pm 16.31$), being 55.56% male and 44.44% female, and most of them (77.78%, values 6 and 7 from Likert scale) use their smartphones very often throughout the day.

The results show that 33% of users thought they needed a tutorial to use the application. Two of them wrote that the application should give a better signal when the user is in the activity area, and another two wrote that the *Birds of Prey AR* mini-game needed a tutorial to teach the relationship between the birds' silhouettes and their names, before starting the gameplay.

The following questions (see Table 3) use the 7-point Likert scale, ranging from "Strongly disagree" (1) to "Strongly agree" (7). The positive results show that having collectable species may entice exploration. Also, the users thought the application had an effective educational component, being in alignment with the application goal, of disseminating scientific knowledge.

The questionnaire's second part used the System Usability Scale (SUS) (Sauro, 2011). The average score was 85.74. Besides being above average (68), it is also above 80.3, meaning that, as said by Sauro (2011), it ranks in the top 10% of the scores with an A grade (ranking goes from A+ to F).

The final question was a comments and suggestions optional field. The answers were grouped as: 1) appreciation comments, 2) UI improvement comments or 3) *Birds of Prey AR* tutorial comments.

Table 3: Results from the usability test at the park.

Questions	Median	Q1	Q3
The app worked as expected	7	6	7
The map was very useful	7	7	7
The map was easy to use	7	6	7
The dashed line helped me to identify the path I took	6	5.5	7
The "Birds of Prey AR" game leads to associate the birds' silhouettes with its name	7	6	7
Using AR made the experience more memorable	7	6	7
The notification on the collectables' icon draws attention to interact with it	6	4.5	7
Having collectables makes me want to try all activities	6	6	7
The species' information was interesting and educational	7	6	7
The app had an effective educational component	7	6	7
I liked the app visuals	7	6.5	7

The 1) appreciation comments show the participants liked the experience and the application, with some of them, writing they would like to see it being expanded with more activities and supported in other operating systems. There were also multiple instances of participants asking from where they could install the application into their device. The 2) UI improvement comments were mostly requests to make more visible the map's dashed line and the activities' notification. The 3) *Birds of Prey AR* tutorial comments were made by multiple participants, stating they felt the need for a tutorial that would better introduce the birds before the gameplay started.

Overall, the results showed that no significant modifications are needed, confirming the positive effects of the adjustments made after the preliminary study. An example of this is the lack of comments about tiredness or any discomfort while playing *Birds of Prey AR* during this test.

6 CONCLUSIONS AND FUTURE WORK

Mobile devices provide almost limitless opportunities for developing creative and interactive solutions for education, tourism and entertainment.

The Biological Park of Gaia is a tourist location that attempts to expose the region's Natural and Cultural Heritage to its visitors. However, the available information should be more noticed by them.

A mobile application prototype was developed to be used while visiting the park and, to test the guidelines of the proposed framework. Preliminary studies allowed fixing detected issues and improve the prototype. A final usability test, more representative of the experience, was performed *in loco* to evaluate the application.

The results were very positive, indicating that location-based mobile applications that integrate AR and gamification elements improved the visitors' experience while at the same time disseminate scientific knowledge. However, the small sample size does not allow for this conclusion to be definitive. A larger user sample and different contents are needed to help to prove such claims.

For future work, some issues should be addressed, such as the lack of information, before the *Birds of Prey AR* gameplay starts, to help associate the birds and their silhouettes. The dashed line could be thicker to be more visible on the map. Adding sounds and vibration when the user is near an activity location could make the notifications more noticeable. The ability to zoom in on the map or expand for other languages other than Portuguese should also be considered. Technically there are some issues with new aspect ratios and the integration with other libraries such as ARkit and ARCore. We will continue to explore this topic of adding multimedia apps for nature parks to enhance the visitor's experience.

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