The Use of an Augmented Reality Application to improve User Experience in Museums in São Luís - Maranhão

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***Abstract*—Museums are often acknowledged as a place to get involved into education, history and the world of art, serving large communities with the access to their exhibits as well as being seen as a knowledge source provided by their guides, collections, archives and others. Whilst visitors' experience in such given contexts may have been almost the same for a long time - in which the interaction with the displayed artifacts and the experience within the context is restrained due to impositions to prevent visitors from handle assets and collections -, in many museums, gradually, the approach towards their visitors has changed as an attempt to improve the quality of experience offered. One strategy applied to improve visitors' experience in an exhibition environment is to use Augmented Reality (AR) as a manner to bring the user into a more active role and witness exhibitions at their own pace. This strategy consists in the employment of Augmented Reality in order to supply the visitor with a more detailed and interactive perspective of the assets presented, extending the comprehension of the surrounding space and adding an extra informative and interactive real time layer. This project's main goal is to provide an augmented reality application to be used by São Luís museums' visitors, in order to make exhibitions more attractive and educative to a large percentage of the population, as long as they have access to smartphones and mobile devices. The developed application was done focusing on fast development and recognition quality. Also, experiments using 2D and 3D shapes were conducted in order to prepare the system for future realistic fiducial markers and real life objects. The results satisfied the usage concepts, although latency and performance are still a concern when regarding multi-targets and connecting to a remote web service. The construction of an AR system has enough support to deliver both tracking and display virtual objects with no major performance loss, hence identifying one target at time and generating virtual content during usage can be done in a scenario such as the museum metaphor, accomplishing the conceptual goals aimed prior to the developed app.**

Keywords: Museums, Augmented Reality, User Experience.

Index Terms:: K.6.1 [Management of Computing and Information]; History preservation; [The Computing Profession]: Miscellaneous—Ethics

I. Introduction

Augmented Reality might be used in diverse contexts in order to bring interactivity to a large set of situations [1]. According to the constructivist perspective advocated by Jean Piaget [2], which defends that the context, experiences and subjective ideas bring forth one's knowledge in a relation where person and environment affect each other mutually, it is now evident that tools for the extension of the real environment, such as virtual reality (VR) and augmented reality (AR), can stimulate the user's constructive development and the interactive learning. Scenarios as museums, historical centres and expositions provide viewers a large amount of artifacts in which spectators can get interested and internalize the momentum knowledge, and according to the spectator's interaction over the environment and objects, learning can be more or less extensible. In that way, the augmented reality satisfies the user's necessity to have a deeper and enjoyable experience. "Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment. [...] In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it." [3]. Hence, it is necessary to state that Augmented Reality is not just a technology, but a set of software and hardware components that need user acceptance to be firmly comprehended and employed - especially in contexts of social and technological integration. In such scenario, the development of a system in the bases of augmented reality, mainly in an inclusive context, requires technologies widely used and reliable. That said, since smartphones and most mobile devices perform common tasks and are largely used amongst the population [4], taking advantage of such equipment presents satisfactory results for both developers and users, with the additional benefit of not compelling the final user to learn how to manage a new type of device, since this sort of device presents many affordance components and its usage is well known. In conclusion, having the development of an application that satisfies at least the users' basic expectations [5], the goal is to ensure that distributed data can be loaded and displayed in a comfortable manner to the final user as soon as any of the trackable objects is identified. The study places itself in a practical development baseline to deepen further considerations and identify best solutions during the experiences. Also, it is intended that the application will be evaluated in real life scenario, where its usage can be tested and approved by the main focus of such research: the final users at the Fort of Santo Antonio Museum.

II. The Fort of Santo Antonio Museum

Museums, in general, have a very similar visitation model. Using an ideal context, where the visitor is in a room with 2D or 3D works, in most real life museum scenarios, it is expected that there will be a description for what the visitor watches, as well as explanations or context for each exposed piece, as well as a title, creation time, etc, for such a piece of work. This context can be improved with an Augmented Reality application using virtualized information to enhance user's experience. For instance: the exposed object in other representation models - a 3D interactive model, for example -, descriptions related to the asset, context, audio explanations, etc. Accordignly, the city of São Luís has several museums and a rich history about its colonization, which with the usage of Augmented Reality may acquire a whole new set of possibilities. For example, the Historical and Artistic Museum of Maranhão that shows the reconstitution of the private life of a wealthy family in the 19th century and works by Marçal Athayde could have its pieces gaining life through a visitor's screen. As a matter of fact, the city is considered a UNESCO World Cultural Heritage for contributing or witnessing a diverse and cultural tradition, and also an example of a portuguese colonial city [6]. In similar fashion, The Fort of Santo Antonio Museum is an example of the existing culture of Maranhão's people. The museum provides a set of pieces that delivers to the public some of the regional vessels models and its related history (Figure 1). This scenario and context is rich for the employment of an AR application, as it already provides an interactive user experience. As so, during the application's development, it had been fancied that the the functionalities should work as a complement of what the museum already had to offer, in an intent to perform a similar experience with a more interactive behaviour using technology. Likewise, the application implements a diversity of functionalities that assures the quality of known experiences, while brings features to permit visitors to capture information regarding the artifacts and even play with 3D copies of the pieces in exhibition.

Some images of the exhibits were used as tracking models to make the application have a more realistic approach and as soon as it is finished, be used in tests in loco at the museum.

Fig. 1. A piece from the Fort of Santo Antonio museum's exhibition.

III. AR Solution

A. Object tracking

Having a place to employ and study the usage of an Augmented Reality app, it is important that real-time information pertinent to the tracked object can be rendered as soon as the object is detected or tracked and that the computational vision offers reliable tracking. This detection can be performed using some approaches, from which we can list: machine learning for the detection of images and/or objects; deep learning for image classification and computer vision; and libraries created to work directly with augmented reality using one of the previous methods with the advantage of already offering an API to render virtual objects, which are highlighted by Google's ARCore, Apple's ARKit, Vuforia Kit and the open source ARToolKit. In this project it has been decided to use Vuforia, given its API documentation and fast development process provided by its toolkit of an AR application. According to Amin and Govilkar [7], The Vuforia platform uses superior, stable, and efficient computer vision-based image recognition technique. Also, Vuforia provides a good compatibility with the chosen engine, taken as development platform, allowing tracking and displaying of 2D and 3D models using either its code API or its UI, enabling a helpful set of features when the product needs to convince its users in a short time and being extensible when more complex scenarios arise. Because of that, one advantage found during development was the good integration provided by the large set of devices attended by the chosen engine, Unity 3D, with Vuforia's API. The lack of problems found while attempting to store images and bundles enabled quickly bootstrap the application in tested smartphones with the safety of having the resources loaded and available once the app is running. However, real scenarios present several problems in approaches based on image processing. One of these problems is lighting. Basically, in this step, pre-processing filters are applied to improve the image quality for the following steps. But, even so, there are other problems and each new context that uses object detection seems to present other ones. Besides of using the benefits of object detection, according to Ren et al[8], there are still several challenges in its implementation. The mentioned work listed the main challenge remains in the detection accuracy and its relation to others aspects or variables. This is one of the topics in the state-of-the-art researches in Augmented Reality and it remains a challenge for real time applications. For that reason, the current research is focused on the application and has a parallel research with feature detection and pose estimation techniques.

B. Web Content Loading

In order to provide a better experience, fiducial markers and targets may be loaded during runtime using an online database, as well as displayable images - which can be stored for a better performance - and textual context-related data. Usually loading content from the web represents high costs to an application, so efforts to diminish these high costs are necessary and encouraged whenever an API call or web resource is required. On that path, an API is called every time the app is started, and, when it is identified that the app has not received updates, an API request is done to a backend, which manages to get every image and asset mapped in a JSON response and after that a single API request is done in order to receive a ZIP file with the media objects that will be used as resources by the application. In that way, asynchronous routines were written as form to load required data without major lack of performance and as an attempt to not harm other components' execution. Loading web resources is a necessity if the product needs to scale for a bigger set of environments, thus tests need to be done for preventing crashes and excessive waiting time. One way to test if loading resources from an API was feasible is using a mocking API. Naturally, when it comes to get only text data, the request is done with no delay nor harmful response waiting. However, when a larger resource is required the delay may be presented impracticable. This is a great concern for the necessity of loading dynamic resources, so then one way to work around the situation is to download all the necessary resources and store them as project assets, hence exempting the user's smartphone to require those resources in every application setup, hence easing the delay and preventing crashes. The approach of receiving web data permits the application to use a back office, which, making use of an API, supplies the app with custom data and makes the project more scalable. This could, for example, support many different museums with their own exhibitions and assets. In the mocking, API image and GIF resources were described as URI addresses, so a different request was done to every larger resource. This test was used as a JSON response, consumed by a C# module. A snippet of the JSON response can be seen below.

```
{
"name": "barco",
"imageURL": "https://i.imgur.com/ab.png",
 "dataInfo": {
    "text": "A canoa costeira maranhense,
    uma das embarcações artesanais...",
    "description": "Barco Maranhense"
  }
}
```

Code Snippet 1: API Response A similar approach is taken while constructing a backend API. The formula tends to be almost the same, but much more information is added to ensure security, data validation, file information, and others, as a manner to hold control over the assets stored in a data storage mapped using relational databases. The employment of a back office introduces several advantages to the application, for example:

1) protect data from unauthorized people;
2) manage information in long-term;
3) ease uploading and downloading by a single pipe;
4) scalonate to new possibilities without harming the app itself.

In this way, one architecture similar to what is thought to be done is the PlanetarySystemGO[9], where a back office plays the role of inserting, updating and deleting resources that need a database do be held as well as a sort of storage.

C. Component Based Application

For the experiments to work the project was done using Unity3D platform, including the programming language C#. Unity offers a large set of tools to work with various kinds of projects and it is the most used platform in game and AR development segment, consequently most of the AR libraries and components are supported by Unity. The use of components is not a new approach, but it has been used extensively in the last decades. Also, according to [10], in the software engineering area, it shows that this approach increases productivity, save costs and improve quality of the generated products. Also, the engine has a great advantage in AR development, which is the possibility of working with the platform in a generalist manner, which means that if the project needed a different approach towards image recognition, library or tool set, it would be easier to change the project's dependencies when compared to a different platform, since different parts of the system can be encapsulated using its component separation perspective. The overall steps of the entire application is shown in Figure 2, in which describes the starting point where the application starts and loads in a parallel form the objects that are going to be tracked as well as the information come through API call. In that process, the response is processed and it is checked whether media resources are stored locally or not. In a positive case, the resources are loaded and mapped based on the relative tracking objects, otherwise, the resources are downloaded and stored locally, being mapped in the same process described. After setting resources and application up, the user's cam is initialized and the tracking is already enabled, identifying all target objects that come at sight. Working in separated modules allows developers to focus on different problems while services are maintain strict to their scope. That is possible using the correct architecture to organize folders, resources and, principally, scripts in Unity.

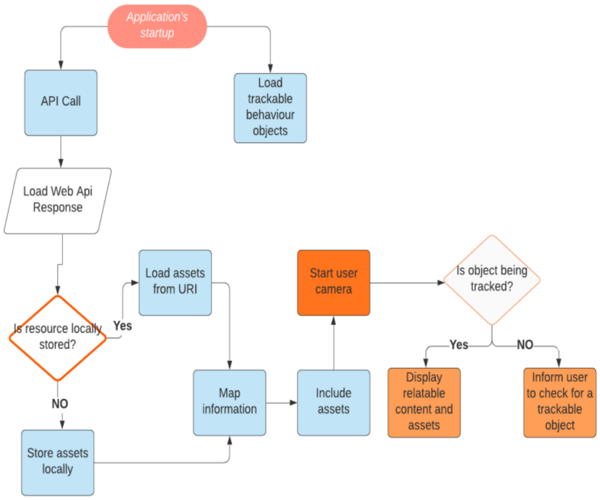

Fig. 2. Information loading steps/modules.

D. Designed User Interface

The designed user interface has simple integrated components that can be arranged and viewed alongside with the observed scene. Using the API component canvas, the object was created to receive a panel containing textual components, which would be loaded in real time and displays detailed information as soon as the mocking API is called. Besides the canvas, the images are used to create visual components to be added to the screen when loaded from the API. Additionally, a button is placed on the inferior left corner of the screen, so then a user may use some non-crucial features, as screenshot button, application's configuration and share current information being displayed, for instance. As the components are organized to be shown in harmony, they have to be set in spots where they will not overtake any important visual element, producing an experience loss on this process. All components are designed to be displayed as what is shown in Figure 3. This allows textual components, image components and UI components to be well integrated within the application's visual environment.

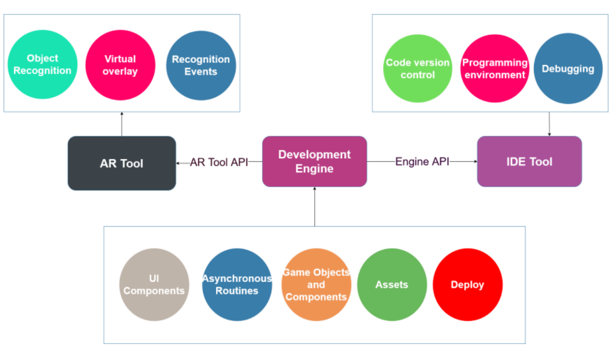

Fig. 3. Component-based application mockup.

These image components are currently being placed on top of the tracking object, but this is a testing behaviour and it is intended to be tested with users from the museum in order to provide a better user experience. The Vuforia API allows several resource types to be shown to the user. For this reason, both 2D and 3D objects are thought to be evaluated in a further moment by users.

IV. Results

The set of technologies chosen to accomplish the main Augmented Reality application tasks implemented the main necessity of an AR application: to show additional and context-related information. The component-based based solution using the integration of Vuforia object detection API and Web Content loading information provided responses detailed in the Table 1. The tracking time after the application is running is described in Table 2. The total time spent in the setup process was registered as being of 3928ms, in contrast to first approaches, which used to mark 12 seconds, in average, for they were implemented using synchronous processes to download and store assets and resources. Since Vuforia's tracking is always enabled as the application default behaviour, object identification is done in real time with no latency, for this reason it is neither useful nor practicable measure object identification at runtime. Further acceptance tests and validations should be conducted once the world pandemic has been surpassed, leaving a path open to apply the project in real scenario.

TABLE I
Integrated information loading resources through API.

Object	Information Size	Time retrieval	Asynchronous
Text request parse	2.05 kb	3680ms	NO
Boat sample	164 kb	1125ms	Yes
Gif Sample	730 kb	1073ms	Yes

TABLE II
Integrated information based on Recognition Time.

Process	Time spent	Real time perception
Display image and text	0.7ms (average)	No
Display only text	0.03ms (average)	No

The obtained result is show in Figure 4 and can provide enough value to the final users, both for the user is inside the Fort of Santo Antonio museum or in a Augmented Panoramic approach [11], that is most used in training environment but can be used in observation scenarios as museums.

V. Conclusion

It has been acknowledged that the employment of an augmented reality application in the scenarios of a museum is not only possible, but feasible and scalable. Although minor problems regarding image processing and performance may be easily solved using multi-threading computing, asynchronous operations and handling properly resources, other topics still represent a concern, e.g., illumination, user cam quality and condition of exhibit pieces. The implementation of Augmented Reality applications is a real necessity nowadays. The AR technology has achieved a reliable stage and the

Fig. 4. A typical Maranhão's boat model as a tracking object.

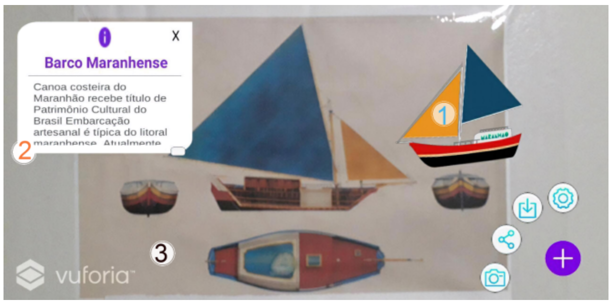

Fig. 5. Image tracked and elements being displayed. In ascending order: 1 - image rendered after object detection; 2 - informative panel containing information based on detected image; 3 - target image.

integration with different web API's can produce fast and good applications. We intend to use the developed application with tourists and employees from the museum, and apply some questionnaires for user experience evaluation. Although Vuforia is the current solution in operation, in future works we intend to use other libraries and solutions (e.g, OpenCV library, Unity Foundation, etc), which are able to perform some of the tracking tasks developed so far with the advantage of being open-source and/or free o payment alternatives. Besides that, the detection step can be improved using integrated techniques such as deep learning using Tensorflow, but with some challenges as the Pose Estimation of the detected objects. Furthermore, tests shall be conducted once the pandemic risks become low enough to not put any tester in danger, being that a necessary step to validate and conclude the project done so far.

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