Design and Development of an Augmented Reality Application for Art Galleries and Museums in Peru

Kenzo Ettore Van Waerebeek Alfaro[1], Diego Daniel Linares Correa[2], and Daniel Alejandro Subauste Oliden[3]

[1,2,3] Universidad Peruana de Ciencias Aplicadas, 15023 Lima, Peru, u201411582@upc.edu.pe, u201410419@upc.edu.pe, daniel.subauste@upc.pe

Abstract*– Augmented reality is a popular technology for commercial, cultural, educational uses, etc. Likewise, the digitization of elements present in museums or art galleries offers an advantageous opportunity to use new tools with novel technological characteristics. In the present study, a mobile application will be evaluated, developed with the Unity 3D work environment and the Vuforia software development kit, which presents different virtual elements using augmented reality by identifying specific image markers. With the use of this mobile application, this study will validate how useful it is to improve the experience of visitors in their attendance at different cultural places in Peru. Through a case study of 30 participants, the impact on the experience, usability and usefulness of the mentioned application is qualitatively evaluated. The findings found that the tool was accepted as intuitive, informative, interactive, and novel.

***Keywords*-- Augmented Reality, Art, Application, Museum, Gallery, Smart Phone.**

I. Introduction

Sculptures, paintings, photographs, and other elements exhibited in museums and galleries can be considered as art, which is defined as a manifestation of human activity in a certain period [1]. That said, one of the biggest challenges of the establishments is maintaining a relevant assistance for the business, a problem linked to the experience of visitors during a tour. In 2018, it was found through surveys that in Peru only 14.8% of respondents had visited a museum since 2017 and that in less than 10 years dissatisfaction with the offer of cultural and recreational activities in Lima had doubled [2].

Faced with this problem, different technological solutions are already being used in cultural establishments to attract, inform, and entertain in non-traditional and innovative ways. The use of this type of solutions is profitable, since they provide the ability to adapt the particularities of an environment and, in this way, improve the experience of a visitor [3]. The importance of this lies in the fact that the lack of personalized experiences means that visitors do not get to visualize items or objects of interest to them within an installation, causing a potential loss of customers [4].

In the case of augmented reality, there are reasons to implement such technology in a museum or art gallery and different alternative solutions. For example, information can be displayed through digital panels, as studies indicate that visitors who are interested in learning, also seek to experience different sensations and emotions [5]. Furthermore, augmented reality enables inert objects to come to life with animations, which is helpful for abstract collections that require more interpretation [6]. Then, it is known that learning in museums has become more meaningful by considering the interaction by augmented reality with exhibitions [7]. Similarly, users who have used augmented reality applications in cultural establishments managed to feel more involved with presentations [8].

The solution must be encompassed since establishments such as those mentioned above are a relevant pillar of our culture [9]. Regarding the benefits, the creation of an application that uses augmented reality technology is proposed to contribute to the improvement of the experience of museums and art galleries attendees and, in this way, a potential increase in the attraction of a larger target audience. With this said, high levels of satisfaction and motivation with the use of this solution are expected, leading to a greater disposition to using mobile applications and augmented reality in cultural establishments. The present document will address preceding studies related to this subject, the development process of the application in mention, the validation and results of the final product and conclusions.

II. General Review

A. Augmented Reality

It is defined as the display technology in a device that allows the user to combine information from the real world and the virtual world in real time. One of the most common ways to use augmented reality is through smartphones or tablets (Tr. Smart Tablets). Both portable devices are available worldwide and are considered the most suitable for implementing display technology, as they allow any virtual content such as 3D models, 2D images or informational text to be added to their real position on top of a scene captured by the device's camera [3]. This enables interaction and vision of real elements, which is achieved by superimposing visual elements. In this way it is possible to unite a virtual environment with a physical environment [6].

B. Vuforia

It is a well-used augmented reality platform, since it provides an advanced analysis capacity based on image recognition, known as Image Target (Tr. Image Marker). Vuforia detects natural features in an image and compares them to a database of stored resources. In addition, it can provide a web service that allows an Image Target to be stored in the cloud to be processed and evaluated in real time with the image captured on the camera of a device [3].

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2021.1.1.378
ISBN: 978-958-52071-8-9 ISSN: 2414-6390

B. Unity3D

Unity 3D is a popular video game engine due to its development environment, where spatial understanding and perception is facilitated, which allows the user to have a real feeling with the experience of the visualized objects. It is a development environment that provides a convenient platform to develop games, 3D animations, and interactive models, among others. Additionally, Unity 3D uses C # and Java programming languages, which developers can easily learn [15].

III. Related Work

It is important to highlight previous research. In the case of augmented reality, in [10], an application integrated a navigation system where rooms of a museum are shown and had slides of images, 3D animations, a graphic introduction and information from the museum. Maya software was used for the creation of models, Unity for the creation of animations and the graphical interface of the application and the Vuforia software development kit to allow augmented reality functionalities. Secondly, in [11] an application was developed to improve the understanding of meanings in religious art and to facilitate the initiation of intercultural dialogues for the Diocesan Museum of Milan. This application enhanced with videos, texts, images, and hyperlinks hidden aspects of objects. Likewise, user comments were connected to create a kind of social network for the exchange of ideas using a web server with a MySQL database. Also, in [12] the Vuforia software development kit was used with a magnifying glass tool, consisting of the union of an iPhone 4S inside a wooden cover. This study made the use of the application during a thematic guide inside the Allard Pierson art museum, called "treasure hunt", that is, with a narrative tour and a defined theme. The app also offered interactions to make visitors explore the artifacts in the collection in a traditional way.

There are also studies that use augmented reality in addition to or adapted to other technologies. In [13], a technology called Leap Motion was used to follow the movements and signs of a visitor in interaction with a 3D element. This was done on a server, which was connected and positioned on the physical surface of the device where augmented reality was displayed. Certain signs identified by the Leap Motion allowed the change between 3D artifacts displayed in the application, for example.

In [14] direct and indirect augmented reality was used in an application depending on the location of a visitor and the orientation of a device with Bluetooth. In direct augmented reality, overlapping changes were observed in the image coming from the device's camera when aiming at a specific place; in the hint, an “enlarged cube” was shown which had the shape of the room where the user was with a 360 view of objects in augmented reality. In contrast, in [15] another application used the IBeacon tool to detect the positioning of people indoors precisely in real time and record their visiting time at a cultural establishment. This proposal sought to analyze the behavior of visitors to exhibitions to create efficient navigations with elements of augmented reality for users without the need for image markers, but rather by analyzing their current position.

Likewise, there are technological solutions that do not use augmented reality but have been implemented to solve the exposed problem. For example, in the proposal given by Lee et al. [16], a system was developed using augmented reality and other methods of geometric and radiometric calibration to project textures on moving 3D projection surfaces without distortion of perspective or problems related to ambient light. In this way, virtual objects with 3D floating effect, photorealistic appearance, precise depth, and dynamic projection would be exhibited.

There are even studies that propose solutions that do not use techniques in relation to the superposition of elements. In [9], it was proposed a gamification method integrated into a mobile application to advertise museums and stimulate customer interest. The designed game rewarded users for finding new museums registered in the app. Being able to verify the contents of these created motivation to know and explore the exhibited items.

In all the examples mentioned above, for each system or application, a software development kit and a different development environment must have been used to meet the research needs when developing technological tools. There are studies that follow the same line of Greci, Kyriakou & Hermon or Schönhofer et al. [10, 11, 13], who used Unity and/or Vuforia. In contrast to these, in 2018, the Wikitude software development kit was used for the development of "SvevoTour", an application through which users would be able to see images, videos, 3D shapes and hypermedia as elements of augmented reality of a museum of literature. This was published in Wikitude Studio, a platform that used a cell phone camera and sensors to recreate a virtual view on the screen of the mobile device [17]. On the other hand, Abbas et al. [18] used technologies such as MySQL, WebGL, PHP, JSON and HTML5 for the integration of an artifact management system with augmented reality aimed at museum employees.

IV. Design and Implementation

A. Concept of the Application

The application developed for this project managed to be as close as possible to a tool such as sketches, informative text frames and audio guides of a cultural establishment. The mobile application has a striking identity and interfaces for the end user based in local ancient and urban art (as seen in Fig. 1). When using the application, you can see elements of augmented reality such as 3D models, audios, and animations by pointing to an image that the user wants from a repertoire hosted in a database in the cloud. The application has 2 languages (English and Spanish) and has a concise menu of instructions. Available artwork to view is displayed on a slide bar. The given name for the application was "T'asRA", merging the word 'picture' in the Quechua native language and the acronym for 'augmented reality' in Spanish ('RA').

Fig. 1. Mobile application's main menu having chosen the English language.

B. Selection of Elements

The selection of the 3D models shown in the application was initially made in the Unity resource store called "Unity Asset Store". The lowest cost models that had end-user friendly animations were selected and the weight of 30Mb per model was set as a limit to take care of the weight of the application. In some cases, different 3D models were brought together on a single stage to display them at the same time.

After the selection of the models to be used, the works of art were created that would be accompanied by them and that would be entered into the database later (in .jpg format). For this, it was necessary to have graphic design resources, since these would be provided with the chosen models and animations so that they can make a sketch of a related work of art and, finally, choose the style of painting to finish said work. On the other hand, it was chosen to use background music for the navigation of the interfaces and sounds that are attached to each 3D model and its animations.

C. Application's Architecture

The physical architecture diagram (as seen in Fig. 2) serves the same purpose as a deployment diagram, which is intended to document the physical operation of a system's infrastructure or its runtime environment and illustrate how containers in the model map to the infrastructure [19]. On the other hand, the logical diagram was designed to satisfy the functionalities required in the final version of the application (as seen in Fig. 3). All the components were chosen considering variables such as cost, evaluation of the learning curve for use, existing documentation, analysis of preceding literature and considering work carried out in related studies.

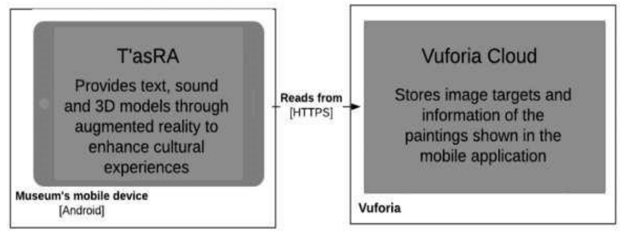

Fig. 2 Physical architecture of the mobile application (T'asRA) with presence of the digital repository for images Vuforia Cloud.

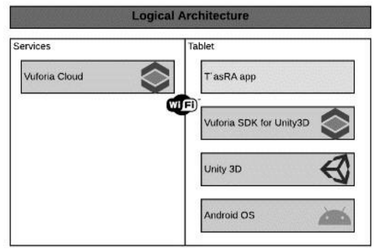

Fig. 3 Logical architecture with presence of Vuforia Cloud (image repository) and Vuforia SDK (software development kit) component used for augmented reality functionalities.

In Fig. 4 the interaction between components to recognize the paintings that are stored in the database is shown. The Vuforia component uses the images of the camera shared by the Unity 3D component to compare them with the images stored in Vuforia Cloud (a digital repository). When there is a match, it sends the information of the recognized painting, and the Unity 3D component shows the corresponding animations and sounds for the user. Therefore, this process is repeated each time the device's camera points at a different work of art.

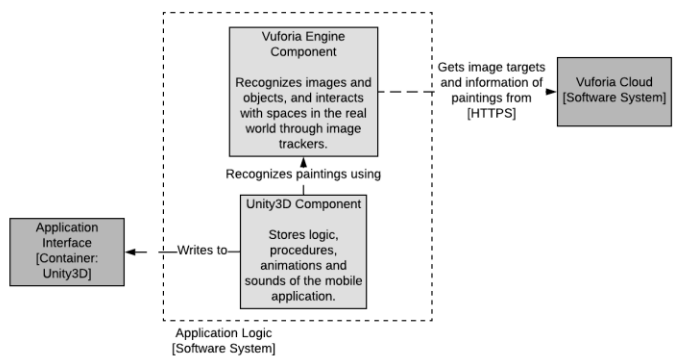

Fig. 4 Component Diagram of the application with presence of Unity3D (chosen work environment), Vuforia Engine and Vuforia Cloud (both part of the software development kit for augmented reality functionalities).

D. General Development

First, Vuforia libraries, packages of the selected 3D models, sounds and graphic elements provided by graphic design resources were imported into the Unity 3D work environment. The “DOTween” library was also imported to handle transitions between screens.

Second, it was confirmed that the version of Unity that was worked with during development would be supported for a considerable period. Once this point was assured, the project was configured for use in the Android operating system and with the necessary specifications to be displayed in the best way and in the best resolution on the test device of the project, a Samsung Galaxy Tab A 2019 tablet.

Subsequently, we proceeded to program the start of the interface presentation after the introduction or "splash" of the application and assign the background sound to the navigation. Then, we proceeded to position and program different functions of the interface elements, especially the buttons and transitions. Next, the database was configured from the project in Unity, which is located on a web platform containing the pictures associated to the final 3D models used in the application (as seen in Fig. 5).

Finally, the operation of the Vuforia libraries was developed to be able to work with the different 3D models and sounds used throughout the project. Two arrays were defined, one of models and the other of sounds to be used when reading an image marker.

The final application has an attractive range of colors and images on the different screens, which represent art of different styles. In addition, it features background music from a piano and transition animations between interfaces.

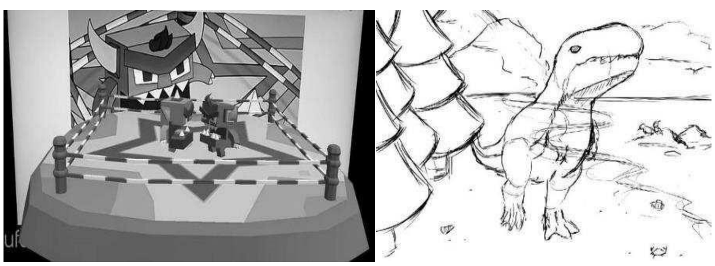

Fig. 5 3D model used in the application and finished sketch of an image target.

V. VALIDATION

A. *Context*

Before explaining the results and validation of the project, it is key to mention what happened around the context of the research during said process. Due to the global situation regarding the outbreak of the COVID-19 virus and a total confinement in Lima, the city where all the work was carried out, it was decided to remotely validate if the application met its objective. The works of art were shared with users through an online folder so that they can be downloaded and used by the user. Each of them was explained how to install the application on their own devices (in .apk format) and how to open the works of art (in .jpg format) to carry out the necessary tests. After this, each user filled out an online survey so that the responses could be collected and analyzed, and some agreed to take a photo using the application. Each survey could only be completed once per IP address and the national identity document, and a personal email were requested from each person. By completing each survey, users indicated that they agreed to the use of their responses for academic purposes and exclusively for our research.

It should be noted that this decision was made because of the situation, but also, because if the confinement were lifted, it would be very likely that users, like any citizen, would fear being together with other unknown people in a closed environment.

B. *Sample Data*

The following points were considered for the final sample of surveyed users: Be over 14 years old so that the user can have a concrete notion of the purpose of the application and know that it has had experiences in cultural establishments. That the respondent, being an elderly person, could understand how to install the application with or without the help of project managers. Have a final sample with a similar number of women and men. Have a final sample with varied ages. If you are a foreigner living in Peru, have an immigration card. Have at least 20 respondents. The possibility that a respondent never or almost never visits establishments such as museums and art galleries was evaluated. This would be valid, since it is relevant for the project to know if the application improves the experience of people who do not frequent these places, as this could even motivate them to visit those places. The final version of the survey had a maximum of 15 questions, so that this is short and pleasant for the user. Below are data on the final sample: A total of 30 people was surveyed. 16 men and 14 women were surveyed. 22 people between 20 and 39 years old, 3 people between 14 and 19 years old and 5 people from 40 years old and older were surveyed. The average time for completing the surveys was 2 minutes and 46 seconds. 20% of the respondents indicated that they “frequently” attend cultural establishments such as museums or art galleries; 30% "once in a while", 40% "rarely" and 10% "never".

C. *Results*

Firstly, users were asked about their experience using the app; 96.67% of the respondents had a positive response. 50% indicated feeling very satisfied, while the remaining 46.67% indicated being only satisfied (as observed in Table 1).

Response Options	Answered
Very Satisfied	50.00%
Satisfied	46.67%
Neither satisfied nor dissatisfied	3.33%
Somewhat unsatisfied	0.00%

Unsatisfied	0.00%

Table 1. Percentage distribution of respondents' responses regarding their level of satisfaction with the use of the application.

Then, users were given different qualifying adjectives to relate to the application. It was varied between positive, negative, and neutral adjectives to acquire the most accurate and sincere information from the user's point of view (as observed in Fig. 6).

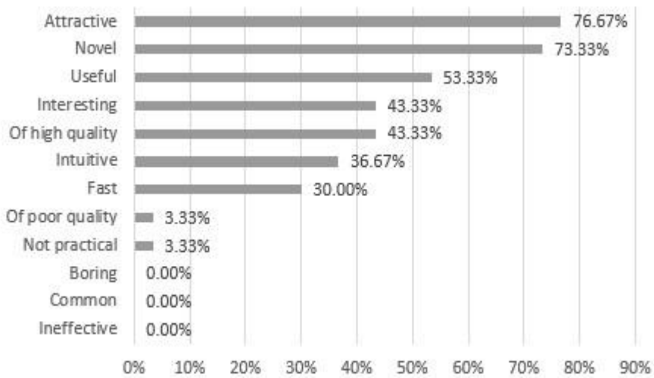

Fig. 6 Percentage distribution of responses on the most qualifying adjectives attributable of the application.

In third place, 73.33% of people indicated that they are willing to use a similar application over a brochure or audio guide in the future. The rest of the respondents indicated being simply willing, but not unwilling (as observed in Fig. 7).

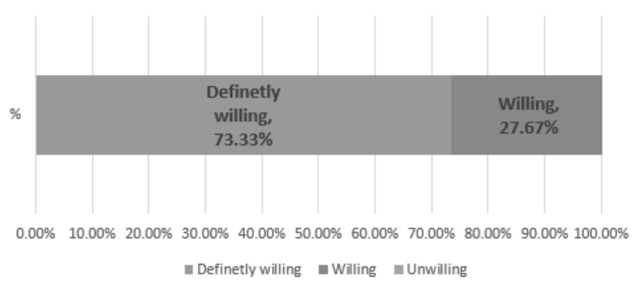

Fig. 7. Willingness of users to use a similar application in the future.

Finally, 100% of the respondents, after using the application, consider that similar applications would allow the improvement of their general experience when frequenting cultural establishments such as museums or art galleries. Regarding this result, it is important to mention that it is true even for users who initially indicated that they never or rarely visited this type of place.

VI. Conclusion

To conclude, the design and development of a mobile application that uses augmented reality for art galleries and museums in Peru was presented. The proposal allows viewing virtual elements, such as 3D models and information on works of art, by identifying specific image markers. This was achievable using the technologies chosen for this research, supported by the results of previously reviewed investigations, and considering a vast number of projects that have already been carried out in the existing literature.

Unity 3D was chosen for its ease of use, shorter learning curve, and ease of deploying applications on both Android and iOS. Subsequently, it was decided to work with Vuforia, due to the completeness of its functionalities, ease of integration Unity 3D and its abundant and detailed documentation, and with Android as the target operating system, since the costs involved would be lower and the market distribution statistics for the use of mobile devices indicate that it is the most widely used.

It was possible to define and design a viable physical and logical architecture and according to the application's functionalities; Graphical documentation models were used to represent the application with a small number of resources while still being detailed enough.

Surveys were used to determine user satisfaction, which were delivered to the respondents after using the mobile application. The results showed that users are satisfied with the use of the developed application and are willing to use this proposal or similar solutions in the future. Furthermore, the most outstanding feature was "attractive"; in this way, it has been proven that the proposed solution is practical and manages to have a positive impact on the experience of visitors to cultural establishments in Peru.

Acknowledgment

Thanks, and praises to our families, which without their constant support and love this work could have not been realized. Second, to our adviser, who brought a lot of experience to the team involved in the investigation. Last and not least, to all the people who gave their opinion and reviews of the application developed, therefore contributing heavily to the final product's looks and functioning.

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