

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería de Sistemas e Informática

Tesis

**Development and Implementation of an Augmented
Reality Application for Immersive Interaction with
Cultural Heritage at the Wariwilca Museum**

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Development and Implementation of an Augmented Reality Application for Immersive Interaction with Cultural Heritage at the Wariwilca Museum

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Abstract— This research paper explores the impact of Augmented Reality (AR) as an educational tool at the Wariwilca Museum, located in Huancayo, Peru, with the aim of improving the experience of visitors, especially students. In a context where the transmission of information in museums is limited to physical guides and traditional exhibits, an AR-based computer system is proposed that allows a richer and more dynamic interaction with museum objects through 3D models and digital views. The research is developed under the line of technologies for education, highlighting the potential of AR to transform learning in museum environments. To evaluate its effectiveness, a survey was applied to students before and after their experience with the AR system. Moreover, the results show a significant improvement in three aspects: knowledge acquired, experience in the museum and general satisfaction, where 82.30% of students aged 14 and 15 reported a positive experience, highlighting the interaction provided by the augmented reality app, which facilitated a better understanding of historical and cultural content. This study shows that the implementation of technologies such as AR can significantly improve the understanding of the objects and history presented in museums, offering a more immersive and accessible experience. Furthermore, the data obtained offers valuable insight into how AR can be effectively integrated into museums to enrich teaching and promote more active interaction with cultural heritage.

Keywords— *Augmented reality, 3D models, educational technology, museum.*

I. INTRODUCTION

Museums, traditionally conceived as static repositories of history and culture, face the challenge of reinventing themselves to meet the demands of an increasingly demanding and digitally connected public. The traditional experience, focused on passive observation of objects behind display cases, is no longer sufficient to attract and maintain the interest of new generations.

In response, museums have begun to integrate technologies such as augmented reality, which allow the fusion of virtual environments with real scenes, achieving greater immersion and optimizing both the design and interactive experiences in their exhibitions [1]. Similarly, this challenge also affects the Wariwilca Museum, in Huancayo, Peru, which despite its invaluable cultural heritage, faces the need to innovate and establish deeper connections with its audience.

Augmented Reality (AR) is presented as a disruptive technology that redefines the museum experience by superimposing virtual elements on the real environment. This tool allows visitors to interact in a more immersive and personalized way, facilitating the capture of information through intuitive interfaces that improve human-machine interaction [2]. With AR, users can explore three-dimensional models of archaeological pieces, obtain detailed information about their history and cultural context, and even virtually manipulate these objects, thus transforming their connection with cultural heritage.

The present study focuses on evaluating the impact of implementing an AR system at the Wariwilca Museum. Our goal is to determine whether this technology can improve the understanding of the exhibits, increase the level of visitor engagement, and ultimately contribute to better conservation and dissemination of cultural heritage. Thus through the implementation of this technology, it is expected that visitors will be able to explore objects from different perspectives, access contextual information intuitively and participate in interactive activities that encourage curiosity and learning [3].

To carry out this research, a mixed methodology will be employed that will combine quantitative and qualitative

methods. Surveys will be conducted with students to collect data on their experience before and after the implementation of the AR system. In addition, system usage data will be analyzed to evaluate its effectiveness and identify possible areas for improvement.

The results of this research have the potential to generate a significant impact in the field of museology and in the promotion of cultural heritage. By demonstrating the value of AR as a tool to enrich the visitor experience, this study can serve as a model for other museums seeking to innovate and adapt to the demands of an increasingly demanding public [4]. Furthermore, the findings of this research can contribute to the development of new educational applications based on AR and to the strengthening of the link between technology and culture.

II. THEORETICAL FRAMEWORK

Augmented Reality (AR) has emerged as an innovative tool in the educational and cultural fields, allowing digital elements to be superimposed on the physical environment in real time.

This technology facilitates a more dynamic and visual interaction with information, which improves knowledge retention and promotes active user participation. In the context of museums, AR transforms the traditional passive viewing experience, offering visitors the possibility of interacting with historical objects through 3D models and rich multimedia content, deepening their understanding and emotional connection with cultural heritage [1].

The immersive learning provided by AR significantly increases user engagement and motivation. In particular, by allowing interactive and personalized exploration of exhibits, visitors can access additional contextual information, virtually manipulate objects, and experience historical narratives in an immersive way.

This approach not only facilitates a deeper understanding of the presented content, but also fosters a stronger emotional connection with the heritage, making learning more meaningful and memorable [16].

Furthermore, AR addresses the limitations of traditional exhibits by overcoming physical barriers and engaging younger, technologically-connected audiences. By integrating technologies such as Unity3D and Vuforia, museums can offer accessible experiences both on-site and remotely, expanding their reach and relevance in the digital age.

This type of innovation is crucial to maintaining the interest of new generations and ensuring the preservation and dissemination of cultural heritage in an interactive and engaging way.

III. METHODOLOGY

A. SCRUM Methodology

The implementation of an AR system at the Wariwilca Museum, aimed at transforming the visitor experience and promoting the conservation of cultural heritage, was organized using the Scrum Framework. This agile methodology allowed the project development to be managed efficiently and

collaboratively, adapting to the changes and priorities that arose during its execution [5],

The project began with the creation of the Product Backlog, a prioritized list of essential tasks for the implementation of the AR system. These tasks included:

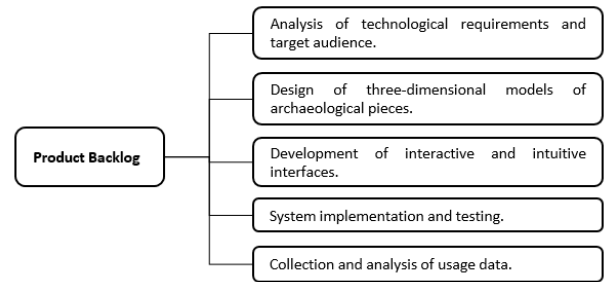


Fig. 1. Product Backlog with five main tasks.

The Product Owner, in charge of managing the Product Backlog, prioritized tasks according to their relevance and the needs of the museum, maintaining the focus on improving the visitor experience.

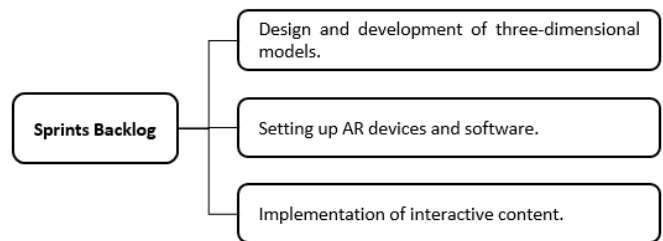


Fig. 2. Activities within the Sprint Backlog.

Development was organized in two-week sprints, allowing for incremental deliveries and constant reviews. During each sprint, selected tasks from the Product Backlog were moved to the Sprint Backlog, where specific objectives to be achieved were detailed.

Roles in the Project

The roles defined by the Scrum Framework were fundamental to ensure the organization and effectiveness of the project:

Product Owner: Represented the interests of the museum and visitors, ensuring that the AR system responded to cultural and educational needs.

Scrum Master: Facilitated the implementation of Scrum, organized daily meetings and retrospectives, and removed obstacles that could affect the team.

Scrum Team: Comprised of developers, designers, and museology specialists, who collaborated to meet the objectives of each sprint.

Deliverables and Increments

Consequently, each sprint concluded with a product increment, such as prototypes of 3D models, functional sections

of the AR system, or improvements to the interface. These increments were evaluated in sprint reviews, ensuring their quality and usefulness before being integrated into the final system.

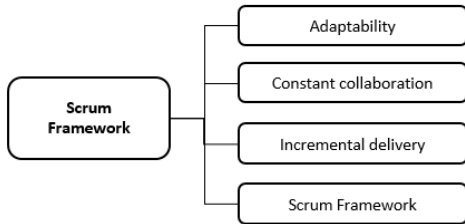


Fig. 3. Parts of the scrum framework.

Expected impact

Expected impact Thanks to this methodology, the project not only allowed the implementation of a functional AR system, but also ensured that each stage was aligned with the museum's objectives.

As a result, it is expected that this approach will serve as a model for other museums interested in integrating innovative technologies that transform the cultural and educational experience of their visitors. Thus, it is also crucial to develop projects focused on the participation of teachers, both at the primary and secondary levels as well as in higher education, that allow them to involve their students in immersive processes [6].

B. AR System Design

Selection of tools and technologies

Vuforia

Vuforia provided the essential capabilities for creating AR experiences. Its robust tracking system allowed real objects to be linked to virtual elements, such as 3D models and informative texts. This tool was integrated with Unity to create immersive content accessible from Android and iOS devices, using visitors' cameras as an interactive window into the cultural heritage [7].

Unity3D

A development platform for interactive content in 2D, 3D, virtual reality (VR), and AR. It is widely used for its advanced graphics engine, support for multiple platforms, and its C#-based programming. It is also popular for simulations, educational applications, and architectural visualization. [8].

Firebase

Furthermore, Firebase was used as a cloud-based solution for data management and storage. Through this platform, information related to museum objects, users, and usage statistics was centralized. Its ability to adapt to various mobile platforms ensured efficient and synchronized data management [9].

QR.io

To improve accessibility, QR codes were generated using QR.io, allowing for a detailed record of people scanning QR codes, including their location and date, as well as offering the possibility of creating custom landing pages without the need for

coding, and providing options such as dynamic and static QR codes and statistics on the use of the codes [10].

GitHub

GitHub was used for version control and collaboration in the development of the system. This tool facilitated the integration of changes, the recording of iterations and the collaborative resolution of problems, ensuring the consistency and quality of the source code [11].

TABLE I. TOOLS AND TECHNOLOGIES

Table Head	Table Head
Vuforia	Creating AR experiences
Unity3D	Designing and rendering 3D models
Firebase	Data management and storage
QR.io	QR code generation
GitHub	Version control and collaboration

3D modeling

The AR project for the Wariwilca Museum integrated various technologies to enhance the visitor experience by viewing 3D models of archaeological objects. Representative pieces of the Wariwilca culture were selected and between 30 and 50 high-resolution images of each object were captured from different angles, using professional digital cameras. These images were processed with Regard3D software, which uses the Structure from Motion (SfM) technique to generate three-dimensional point clouds and create textured 3D meshes based on the original photographs [12].

The 3D models were then optimized by simplifying the meshes and reducing the number of polygons, ensuring a balance between visual quality and performance. The resulting models were integrated into an AR application developed with Unity3D and Vuforia, allowing users to view the archaeological objects in real time through mobile devices. Notably, by pointing the camera at images or points of interest in the museum, visitors could interact with the three-dimensional models and access additional information about the pieces.



Fig. 4. Image capture inside the museum.

C. Content integration

The information collection was based on the following actions:

Bibliographic and documentary consultations: Academic sources, local publications and museum documents describing the historical and cultural significance of the pieces were reviewed.

Expert interviews: Archaeologists and regional history specialists provided additional information about the exhibits, helping to contextualize them within their cultural environment.

On-site analysis: The physical characteristics of the pieces, such as dimensions, materials and ornamental details, were documented through high-resolution photographs and 3D scans.

The information was organized in a database that included historical descriptions, curiosities and multimedia elements, such as images and audios, adapted to different languages and accessibility needs. The content was integrated into the AR system with Unity and Vuforia, linked to QR codes and validated through testing to ensure an accurate and interactive experience.

D. Quantitative evaluation

The study describing the survey could be classified as a descriptive and quantitative study. Its objective is to evaluate the educational effectiveness of the museum visit on Wuari culture, measuring the knowledge acquired by students and their overall experience.

Through a structured survey with a Likert scale, data is collected on how participants perceive their understanding of Wuari culture, the arrangement of artifacts and the quality of information provided during the visit. The data obtained allow to describe the overall satisfaction and educational impact of the museum experience [13].

The survey results indicated a positive impact on students' understanding of Wuari culture, as a large majority claimed to have improved their understanding of historical artefacts and cultural context. The use of AR during the visit also contributed to higher levels of engagement, as students found the interactive experience more dynamic and immersive compared to traditional methods.

IV. RESULTS

Fig. 5, shows a detailed and stylized sketch of the Wariwilca Museum, designed to facilitate navigation and understanding of the space for visitors. This interactive plan offers a clear and accurate visual representation of the various areas of the museum, including paintings and archaeological remains.

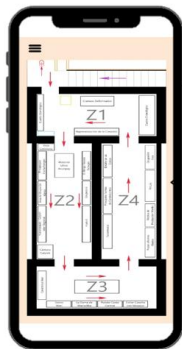


Fig. 5. Sketch and layout of the museum in the app.

In fig. 6, users can easily select between the four main areas of the Wariwilca Museum: Archaeological Area, Exhibition Area, Cultural Area and Service Area. Each area is represented by an interactive icon or button, allowing users to navigate directly to the area of their interest.

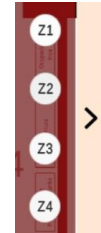


Fig. 6. Separation of 4 areas of the museum.

Fig. 7, corresponding to Zone 1 (Z1), presents images of various paintings, including those of the Wariwilca Sanctuary, as well as the representation of the first Huanca couple. In addition, a 3D image of deformed skulls is displayed, archaeological remains that are physically located in the museum.



Fig. 7. Zone 1 contents.

In Fig. 8, pressing the "View more" button opens a window in the application showing the image in a larger size. In addition, a detailed description of the information related to the image is included. An arrow is also provided offering the option to return to the main menu, making navigation within the application easier.



Fig. 8. Detailed information on selecting an object.

On the left side of the screen, the Home, 3D Scan and Exit options are displayed, allowing the user to easily navigate between the different functionalities of the application.



Fig. 9. Main menu interface.

The Scan 3D option appears both in the windows of the various areas and in the functions section, under the name "Scan 3D". Selecting this option activates the device's camera to recognize QR codes. Once the code is focused, the application displays the image in AR, allowing the user to rotate the phone to view the image from different angles.

In addition, a descriptive text is included next to the image, providing more information about what is being observed. There is also the option to activate or deactivate the audio associated with the image, enriching the interactive experience.



Fig. 10. Qr of one of the 3d images



Fig. 11. View of the 3D image through a mobile phone.

A survey was conducted with students aged 14 and 15, where scores were obtained for acquired knowledge, experience in the museum and general satisfaction with the application of the Wariwilca museum's AR app, very similar to a study where the knowledge acquired was determined once the experience was completed through a questionnaire [13].

The survey results showed a notable improvement in students' understanding of Wuari culture and museum exhibits, with the AR app enhancing interaction and creating an immersive learning experience.

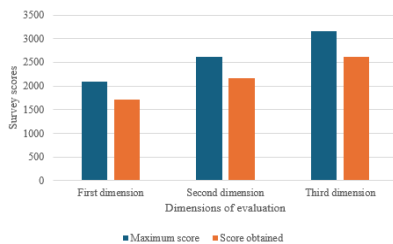


Fig. 12. Comparison of scores obtained and maximum scores of the survey.

First dimension: Knowledge acquired

Specifically, the results obtained indicate that 81.43% of students aged 14 and 15 experienced a significant improvement in the knowledge acquired about the Wuari culture, thanks to the implementation of the AR app in the museum.

This is because, this interactive tool allowed students a more dynamic and effective learning experience, facilitating a deeper understanding while also overcoming previous basic knowledge. Moreover, the high validity of the results reflects the positive impact of technology in education, improving familiarity and understanding of the historical and cultural content presented.

Second dimension: Experience in the museum

In addition, the results show that 82.32% of students aged 14 and 15 experienced a significant improvement in their educational experience as a result of the use of a new interactive tool in the museum. Through this application, students were able to manipulate and examine objects virtually, thereby increased their level of participation and allowed them to explore details of the pieces without the physical limitations of the environment.

Consequently, this digital interaction enriched the quality of the visit, offering a more immersive and engaging experience that ultimately promoted a deeper and more meaningful understanding of the cultural content presented.

Third dimension: Overall satisfaction

The results indicate that 82.86% of students aged 14 and 15 showed a significant improvement in their satisfaction with the museum visit, primarily due to the use of the new interactive tool. The application enriched the experience, offering interactive and adapted content that facilitated a greater understanding and connection with the museum's history.

Furthermore, this innovative approach kept students more interested and engaged, which was reflected in a more positive evaluation of the visit, as the content was presented in a more attractive, accessible and aligned way with their interests and educational needs.

The overall results of the survey indicate a significant improvement in the three aspects evaluated: knowledge acquired, experience in the museum and overall satisfaction. 82.30% of students aged 14 and 15 reported a positive experience, highlighting the impact of the new interactive tool implemented in the museum, such as the virtual reality app. Through this technology allowed for greater participation and understanding of historical and cultural content, enriching both the learning and educational experience at the museum while also increasing students overall satisfaction with the visit.

V. ANALYSIS AND DISCUSSION

For instance, the article on the Wari Willka Museum demonstrates how AR can enhance the educational experience by allowing visitors to interact with historical objects using 3D models [14]. This approach is similar to research, which also seeks to enrich the museum experience through AR. Both studies agree that AR offers a more dynamic and richer

alternative to traditional teaching methods, such as physical guides. In addition, in both, user feedback is essential to optimize interaction and the educational experience.

Similarly, the other article is about the use of AR for 3D visualization of graphic designs, with an emphasis on interactive and collaborative learning [15]. Although the context of application is different, both studies share the goal of improving the quality of learning through dynamic visualization. In the case of the article, AR is applied to graphic design, while in the research in question it is used for cultural heritage, but both show how the technology enhances user interaction and facilitates a deeper understanding of the content.

Finally, in a more general overview, the impact of AR and Virtual Reality (VR) in various educational fields is analyzed, highlighting how these technologies can improve understanding and learning [16]. Similarly, to the research in question, this study highlights the potential of AR to offer a more immersive and accessible experience. Both articles agree that the effective implementation of these technologies in education requires adequate resources and training for users, which is also posed as a challenge in the research being developed.

All three articles highlight the potential of AR to transform learning in a variety of contexts. Whether in museums, graphic design or education in general, AR offers a more interactive, immersive and accessible experience, improving user understanding and engagement. They all agree on the importance of feedback and proper training to optimize the use of these technologies, showing their ability to enrich educational and cultural processes.

VI. CONCLUSIONS

The implementation of AR in museums, as evidenced in the case of the Wariwilca Museum, demonstrates that this technology has great potential to enhance the educational experience. Through the interactive visualization of historical objects using 3D models and multimedia content, visitors, especially students, can interact more deeply with cultural heritage, facilitating a richer and more dynamic understanding. This innovative approach not only improves the knowledge acquired by users, but also increases their level of engagement, making AR a valuable tool for modern museology.

The research results underline that user feedback, such as that obtained through student surveys, is crucial to assess and improve the effectiveness of implementing technologies such as AR. The students' experience at the Wariwilca Museum revealed significant improvements in knowledge acquired, interaction with objects, and overall satisfaction, highlighting the importance of a design focused on user needs. Constant evaluation and adjustment of the system is essential to optimize its educational impact.

More generally, studies on the use of AR in education agree that this technology has the potential to transform teaching in a variety of fields, from graphic design to cultural heritage. However, for AR implementation to be successful, adequate

resources and effective training are required for both users and implementers. These elements are key to ensuring an immersive and accessible experience, demonstrating that beyond technological innovation, success depends on effective integration into the educational and cultural environment.

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