VR and Virtual Tours for Archaeological Parks: The Case Study of Villa Regina

Liliana Cecere
DIIn
University of Salerno
Fisciano (SA), Italy
lcecere@unisa.it

Francesco Colace
DIIn
University of Salerno
Fisciano (SA), Italy
fcolace@unisa.it

Constanza Fiorella Duarte Petti
Interamerican Open University
Buenos Aires, Argentina
constanzafiorella.duartepetti@uai.edu.ar

Flavia Maria Ferrandino
DIIn
University of Salerno
Fisciano (SA), Italy
fferrandino@unisa.it

Marco Lombardi
DISPAC
University of Salerno
Fisciano (SA), Italy
malomabardi@unisa.it

Angelo Lorusso
DIIn
University of Salerno
Fisciano (SA), Italy
alorusso@unisa.it

***Abstract*— The use of immersive technologies for the enhancement and management of cultural heritage today represents one of the most significant frontiers in the digitization of archaeological heritage. This paper presents an application developed for Villa Regina in Boscoreale (Archaeological Park of Pompeii), which includes two distinct digital environments: a 360° virtual tour designed for dissemination, and a virtual reality (VR) environment based on a parametric BIM model, intended for the maintenance and visualization of sensor data (Digital Twin). The study aims to analyze and compare the two solutions in relation to different user profiles, evaluating their functional, communicative and operational effectiveness on several levels. The comparison, supported by simulations and qualitative evidence, highlights the advantages, limitations and possibilities of integration of the two systems. The introduction of a rules-based recommendation system is also proposed to further personalize the experience. The work suggests an integrated and flexible vision of digital technologies applied to cultural heritage, capable of combining public communication and technical management within a dynamic information ecosystem.**

Keywords—VR, Virtual Tour, DT, HBIM, Immersive Environments

I. Introduction

In recent decades, digital technologies have profoundly transformed the cultural heritage sector, influencing methods of preservation, documentation and use. Immersive tools such as virtual reality (VR), augmented reality (AR) and 360° virtual tours offer new opportunities both for public accessibility and for monitoring and managing sites [1]. In the archaeological field, these technologies facilitate historical communication and support interventions on complex and delicate structures, thanks also to the use of parametric models, IoT sensors and simulated environments, which give life to the concept of Digital Twin (DT): a dynamic digital replica of the physical asset, useful for predictive maintenance and structural control [2], [3].

For these tools to have a real impact, it is crucial to tailor them to the needs of different users [4]: on the one hand, the general public, looking for engaging and intuitive experiences; on the other, professionals in the sector, who need analytical and technical tools [5]. Hence the need to develop flexible and multi-level digital environments, capable of differentiating interaction without duplicating the technological infrastructure.

This study is part of this perspective, proposing a comparative analysis of two digital environments created for Villa Regina in Boscoreale: a panoramic virtual tour for dissemination and a VR environment based on a BIM model for management and maintenance. The aim is to evaluate the effectiveness of the two solutions based on user profiles, highlighting the advantages, limitations and potential of an integrated approach to the digitization of assets.

II. Material and Methods

The project is divided into three main phases: data collection, development of digital environments and adaptation to users. This process is conceived as a circular system, in which content and functionality are modulated according to the user's profile and intended use.

A. Data collection

The data collected are divided into three categories: historical and archival sources, which are fundamental for reconstructing the cultural and narrative context; metric and photographic surveys, carried out using laser scanners and photogrammetry, to create accurate 3D models and finally data from IoT sensors, which monitor environmental and structural parameters, essential for horrifying a realistic DT. Each type of data feeds the development of digital environments.

B. Development of digital environments

Based on the acquired data, the proposed work involves the development of two distinct environments, a 360° virtual tour and a VR environment based on the BIM model. The virtual tour, as it is defined, uses panoramic images for dissemination purposes, therefore, it contains informative hotposts and a narrative accessible to all types of users. The VR environment based on the BIM model, on the other hand, is intended for expert users, and in fact includes technical data, maintenance parameters and information from sensors. The model, therefore, becomes a true DT, useful for analysis, simulations and conservative planning.

C. User profiles and goals

The approach of the work is based on the adaptability of content to the level of competence of users, with the aim of integrating different functionalities and purposes into a shared digital ecosystem. The types of users that have been identified in particular are basic users, such as tourists, students and educators and expert users, which include restorers, technicians and archaeologists. In the first case, the goal is above all to discover and deepen the heritage, so there is a need for intuitive and engaging tools. The virtual tour responds well to these needs, just as the VR environment can

be adapted with narrative paths for a more immersive cultural experience. On the other hand, the VR BIM environment, with data updated in real time, meets the needs of the most experienced, as it requires more technical and advanced analytical tools for monitoring and planning.

In addition to the specific functions, the project analyzes the overall effectiveness of the solutions in terms of usability, immersion and adaptability. The scalability of the model is also evaluated, for applications in other sites. The goal is to unify dissemination and conservation in an integrated, sustainable and inclusive approach, capable of responding to different needs through dynamic and customizable digital environments.

III. Case Study

As anticipated in the introduction, the goal of this work was to create, starting from a case study, that of Villa Regina, an archaeological site located in Boscoreale, Campania, two distinct digital environments: a 360° Virtual Tour and a VR environment based on a BIM model, in order to compare its characteristics, advantages and potential based on the type of use and the end user. Villa Regina, a well-preserved rustic villa originally intended for agricultural production, has proved to be an ideal context for experimenting with innovative tools for the enhancement of the minor cultural heritage.

A. VR environment based on the BIM model

An HBIM (Historic Building Information Modeling) approach was followed for the creation of the VR environment, which is more suitable for historic buildings subject to architectural stratification. The process began with a phase of documentary research, useful for reconstructing the history of the villa, its original functions and the materials used. The survey was carried out with laser scanner technology (Leika BLK360) and drone, to obtain a high-definition three-dimensional point cloud and orthophotos without perspective distortions. The acquired data was then modeled in Autodesk Revit, enriching the model with historical and decorative elements to ensure a faithful representation. To complete the model, a network of non-invasive IoT sensors was integrated for environmental and structural monitoring (humidity, temperature, vibrations, visitor flow), with the aim of responding to the conservation needs of the site.

Once completed, the model was exported in .obj format and imported into the Unity graphics engine, where an interactive immersive environment was developed. Navigation paths, interactions with objects and interfaces adapted to different types of users have been defined, thus creating an experience that can be used in VR.

B. Virtual Tour 360

At the same time, a 360° Virtual Tour was created, developed more quickly thanks to the use of the Ricoh Theta camera for the capture of spherical panoramic images. The photographs, taken at strategic points of the site, were connected to each other through interactive hotspots in the 3D Vista Pro software. Information elements and descriptive sheets were included within the tour to enrich the virtual visit, making it accessible even from a distance.

IV. Conclusions

The study highlighted how the integration of different immersive technologies, such as panoramic virtual tours and VR environments based on HBIM models, represents an effective and flexible solution for the enhancement and management of archaeological heritage. The methodological approach adopted made it possible to evaluate the complementarity between the two environments, overcoming the traditional distinction between popular tools and technical analysis tools. The comparative analysis showed that both environments are effective in their respective contexts of use, with an interesting possibility of cross-use: expert users appreciated the virtual tour for its ease of access and consultation, while non-experts showed involvement in the immersive VR experience, as long as the content was clear and accessible.

The results suggest the importance of developing adaptable digital systems, capable of offering guided paths, modular information levels and customizable interfaces. In this sense, the introduction of a recommendation system based on rules and user profiles could improve the experience, making it more targeted and personalized. The integration of real-time data from IoT sensors, then, further expands the potential of the model, transforming it into a dynamic information ecosystem in line with the DT paradigm.

Finally, future perspectives focus on extending the model to other cultural sites and adopting quantitative evaluation systems, to strengthen its experimental effectiveness. The use of intelligent tools, such as artificial intelligence and predictive systems, can make these experiences increasingly accessible, effective and personalized.

References

[1] E. C. Magaña, A. C. Ariza, J. Ruiz-Palmero, and F. D. Guillén-Gámez, "Virtual, augmented, and mixed reality in the University environment: an analysis of scientific production," *Journal of New Approaches in Educational Research*, vol. 14, no. 1, p. 8, Mar. 2025, doi: 10.1007/s44322-025-00027-y.

[2] M. Casillo, F. Colace, A. Lorusso, D. Santaniello, and C. Valentino, "A multilevel graph approach for IoT-based complex scenario management through situation awareness and semantic approaches," *J Reliab Intell Environ*, vol. 10, no. 4, pp. 395–411, Dec. 2024, doi: 10.1007/s40860-024-00224-0.

[3] M. Casillo, L. Cecere, F. Colace, A. Lorusso, D. Santaniello, and C. Valentino, "Digital Twin and Metaverse Supporting Smart Cities: New Perspectives and Potentials," 2024, pp. 111–119. doi: 10.1007/978-981-99-8111-3_11.

[4] S. M. E. Sepasgozar, "Digital Twin and Web-Based Virtual Gaming Technologies for Online Education: A Case of Construction Management and Engineering," *Applied Sciences*, vol. 10, no. 13, p. 4678, Jul. 2020, doi: 10.3390/app10134678.

[5] P. Barra, M. Giammetti, A. Tortora, and A. Della Greca, "Redefining Interaction in a Digital Twin Laboratory with Mixed Reality," 2024, pp. 295–307. doi: 10.1007/978-3-031-60611-3_21.