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DIGITAL SUASA: GENERATIVE AI AND MIXED REALITY FOR ARCHAEOLOGICAL HERITAGE COMMUNICATION OF THE DOMUS OF COIEDII

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Abstract

The integration of eXtended Reality (XR) and generative Artificial Intelligence (AI) opens new perspectives for enhancing archaeological heritage. Focusing on the Domus dei Coiedii in Suasa, the research presents the development of an in-situ Mixed Reality application and a museum videomapping installation. The methodological workflow merges terrestrial laser scanning and optimized 3D modeling with AI-driven tools, employed to animate historical mosaics and reconstruct fragmentary frescoes. By introducing a virtual narrative avatar and specific gamification mechanics, visitors are encouraged to actively explore the physical remains. This approach fundamentally redefines the relationship between the public and the site, demonstrating how to successfully combine scientific rigor, accessibility, and interactive engagement to construct a conscious digital cultural heritage.

Keywords

XR, Archaeological Heritage, Generative AI, 3D Reconstruction, Roman Mosaics.

1. *Introduction*

Communicating archaeological sites represents one of the main challenges in the field of cultural heritage enhancement. Archaeological remains, often characterized by partial structures or uneven levels of preservation, require interpretive tools capable of mediating between the complexity of scientific research and the public's visiting experience. In recent years, immersive technologies, particularly Augmented Reality (AR) and Mixed Reality (MR), have proven to significantly bridge the gap between raw archaeological data and its comprehension. These digital tools do not replace the direct experience of the site but rather enhance it, facilitating orientation, spatial reading, and historical imagination by integrating interpretive contents and reconstructions directly into the physical space. A highly significant context for experimenting with these forms of mediation is the Archaeological Park of the Roman city of Suasa located in the Cesano river valley in the Marche region, Italy.

Founded in the 3rd century BC following the Romanization of the ager Gallicus after the Battle of Sentinum (295 BC), the city reached its maximum urban development between the 1st and 2nd centuries AD. Systematic excavations have brought to light monumental public buildings and elite residences, most notably the Domus dei Coiedii, renowned for its rich mosaic pavements and complex spatial articulation (Fig. 1).

Despite the high scientific value of the preserved structures, the comprehension of the site by visitors is not always immediate. Designing tools that accompany the public along the visiting path is therefore essential to foster the reading of the archaeological landscape and provide an engaging immersive experience for both adults and children.

2. *State of the art*

In recent years digital technologies have taken on an increasingly significant role in the study, documentation and enhancement of archaeological heritage, contributing to the development of new interdisciplinary approaches based on the integration of advanced visualization technologies (Huggett, 2021). In this context the field of virtual archaeology has progressively

Fig. 1: Archeological Park of the Roman city of Suasa.

emerged (Reilly, 1991), understood as a set of digital methods and tools used to document, reconstruct and simulate archaeological contexts (Forte & Campana, 2017), enabling the representation of historical environments, architectures and landscapes even when they are no longer preserved or are only partially legible (Giligny & Desachy, 2019).

Despite the growing number of studies exploring the use of gamification and artificial intelligence in cultural heritage, few studies address the systematic integration of these technologies within interactive experiences specifically designed for real archaeological contexts. In many cases digital applications developed for cultural heritage focus mainly on the visualization of three-dimensional reconstructions (Merlo & Bartoli, 2021), or on the presentation of informational content (Fanini et al., 2014), without fully exploiting the potential offered by interaction, narrative and audience engagement dynamics (Champion & Rahaman, 2019).

At the same time, the growing availability of digital three-dimensional representations derived from advanced surveying techniques has enabled the development of increasingly reliable digital environments for the interpretation and communication of archaeological contexts (Pujol-Tost, 2019). However, the design of digital experiences capable of effectively integrating 3D data, extended reality technologies, interactive storytelling systems and gamification mechanics still represents an open challenge (Zhao et al., 2025). In this scenario, the integration of Extended Reality (XR) experiences, three-dimensional models and artificial intelligence systems emerges as one of the most promising directions for developing new ways of experiencing archaeological heritage, capable of combining scientific rigor, accessibility and active visitor engagement (Jung et al., 2016).

2.1 Virtual and augmented reality in archaeology

XR technologies have acquired a central role in the enhancement and communication of cultural heritage, thanks to their ability to integrate digital content and real context within immersive and interactive experiences (Innocente et al., 2023), supporting new forms of digital storytelling and interaction (Clini et al., 2023).

Virtual reality (VR) and augmented reality (AR) allow the visualization of three-dimensional reconstructions and informational content within digital environments or directly in real space (Martusciello et al., 2025), offering new ways to explore sites (Bekele et al., 2018).

In the specific case of archaeological sites, the use of augmented reality makes it possible to overlay three-dimensional models and virtual reconstructions onto the material remains present at the place of visit (Vlahakis et al., 2002), facilitating the understanding of the historical transformations of contexts and improving the public experience (Boboc et al., 2022). Studies dedicated to the design of immersive experiences for heritage have highlighted the importance of the relationship between physical space and digital content in promoting a more conscious and engaging form of use (Clini et al., 2022).

2.2 3D documentation and digital reconstruction

At the same time as the development of immersive technologies, three-dimensional acquisition methodologies have transformed the processes of documentation and representation of cultural heritage (Angeloni, 2022). Techniques such as digital photogrammetry and laser scanning now make it possible to generate high-resolution three-dimensional models used for scientific documentation, conservation and enhancement of cultural heritage (Remondino & Campana, 2014).

The consolidation of workflows for the construction of 3D models has made reality-based representation a fundamental step in the digitalization processes of cultural heritage (García-León et al., 2019). In museum and archaeological fields, several studies have highlighted the importance of defining replicable operational pipelines that include the different phases of data acquisition, three-dimensional reconstruction, geometry optimization (Gonizzi Barsanti et al., 2022), texturing and publication of digital twins (Ferretti et al., 2022).

The availability of accurate three-dimensional models has also fostered the development of interactive digital environments based on game engines and real-time platforms, in which cultural contents can be explored and queried by users through interactive interfaces (Roussou & Katifori, 2018). In this context, the design of interaction modalities and the informational structure of digital environments plays a central role in the readability and understanding of cultural content.

2.3 Gamification for heritage communication

Research attention has progressively focused on the development of strategies capable of improving public engagement in digital experiences dedicated to cultural heritage (Liaskos et al., 2022). Among these, gamification represents one of the most widespread approaches to foster visitor engagement through the introduction of typical game elements within non-game contexts (Clini, et al., 2025).

The integration of game mechanics into applications dedicated to cultural heritage makes it possible to transform the visiting experience into an exploratory and participatory process (Lo Pilato et al., 2023). From this perspective, missions, objectives and reward systems do not only perform a motivational function, but also help stimulate curiosity, attention and continuity in interaction, encouraging forms of informal learning and greater familiarity with the proposed cultural contents (Clini, et al., 2025).

2.4 Artificial intelligence and storytelling in Heritage

More recently, the development of artificial intelligence technologies, and in particular generative AI systems, has opened new perspectives in the production and management of digital content for cultural heritage (Nespeca et al., 2025). Artificial intelligence now makes it possible to generate images, animations and virtual characters, offering new opportunities for the design of interactive narrative experiences dedicated to heritage communication (Fink et al., 2025).

In the cultural field, artificial intelligence can be used to develop dynamic storytelling systems and virtual characters capable of guiding users within digital experiences (Gerner, 2024). The integration of three-dimensional models, XR technologies and AI systems therefore represents one of the most promising directions for the development of new ways of experiencing archaeological heritage (Cirafici et al., 2025), capable of combining scientific rigor, accessibility and public engagement (Nowak & Fox, 2018).

3. *Research* aim

To address this need, this research takes the Domus dei Coiedii, located within the Suasa Archaeological Park, as a case study to explore the potential of integrating Artificial Intelligence (AI) and eXtended Reality (XR) technologies in innovating the ways archaeological heritage is experienced. The main objective is to redefine the dynamics of interaction between the archaeological site and the visitor, as well as between the visitor and the museum institution, by introducing forms of digital mediation capable of expanding interpretative and participatory possibilities.

Using a Mixed Reality (MR) digital guide and AI-generated visual content, the project aims to enhance the distinctive features of the site, with particular attention to its complex Roman-period mosaic pavements, which represent one of the defining elements of the archaeological area.

To implement this perspective, the research investigates how three-dimensional reconstructions of the original architectural spaces can be integrated with gamification mechanics to foster active audience engagement.

Within this framework, the study also explores the development of a narrative device designed to guide visitors throughout the interpretative path, with particular attention to the accessibility of content and the involvement of younger audiences.

The investigation is not limited to the archaeological park itself but also extends to the Suasa Archaeological Museum, where the potential of AI-based methodologies is explored to support exhibition design and the enhancement of the displayed remains.

The experimentation led to the development of two main outputs: a tablet-based application designed for in situ use within the archaeological park and a videomapping system conceived for the exhibition setting of the Archaeological Museum

4. *The creative workflow*

Regarding the creative process adopted for the development of the identified outputs, a methodological workflow widely consolidated in the fields of entertainment and film production was employed and adapted to the context of cultural heritage and museum communication (D'Alessio, 2025). The workflow follows the classical structure of pre-production, production, and post-production (Buccheri, 2003). The initial phase focuses on the design of the overall narrative and interactive framework, with the aim of planning the generation of multimedia contents developed during the production phase and subsequently integrated during post-production to achieve the result while optimizing both time and resources.

In relation to the two expected outputs, the pre-production phase was further articulated into four main stages: script, storytelling, storyboard, and animatic. This subdivision allows the structuring of a standardized and collaborative workflow, encouraging strong interdisciplinary cooperation among the various professionals involved in the project. These include engineers, responsible for assessing the technical feasibility of the proposed solutions, and archaeologists, who validate the scientific content, narrative coherence, and three-dimensional reconstructions.

To ensure methodological transparency, digital contents are classified into archaeologically 3D validated reconstructions, and AI-generated visual elaborations, differentiated by dedicated luminous visual overlays to guarantee immediate recognition. The latter were developed through a strict "human in the loop" process, based on a continuous dialogue between engineers and archaeological experts.

This approach guaranteed that even the most imaginative and gamified elements maintained a coherent connection with the cultural context, without claiming absolute historical fidelity.

4.1 Script: defining themes and informational levels

During the script phase, the themes and informational levels to be included in the experiment were defined. Taking advantage of the potential offered by the archaeological park, the rooms to be included in the XR experience were first selected, establishing a two-level informational structure.

The first level concerns the reconstruction of architectural spaces, aimed at illustrating the original appearance of the rooms during the Roman period. The second level focuses on the decorative elements that remain visible today, particularly the mosaic and marble pavements. Specifically, six spaces were selected: the tablinum, the reception hall, the gladiators' room, two cubicula (bedrooms), and the natatio.

These spaces were specifically chosen for the distinctive iconography present in their mosaic decorations, which feature representations of the Drunken Satyr, the Gladiators, Medusa, and Leda and the Swan. For the museum installation, a fragmentary fresco originating from the Domus dei Coiedii was selected as the basis for the videomapping output.

4.2 Storytelling: narrative structure and interactive mechanics

The subsequent phase focused on defining the storytelling of the applications, providing a narrative dimension to the previously identified informational content. In the case of the mixed reality experience, the narrative is mediated through interaction with an avatar, conceived as a digital guide accompanying the visitor throughout the visit. The narrative structure therefore takes the form of an interactive first-person dialogue between the visitor and the virtual character. At this stage, the interactive narrative device underpinning the experience was also defined. Once one of these elements is found among the archaeological remains, users can select it to activate the associated informational content, which includes both descriptive information and the visualization of the three-dimensional reconstruction of the corresponding architectural space or decorative detail. From a narrative perspective, the context for this interaction is introduced in the opening sequence of the experience, which presents the guiding character and explains the exploration and interaction mechanics to the visitor. This phase concluded with the writing of all the informational texts supporting the different narrative components of the experience.
Conversely, for the second output, the museum videomapping system, no textual narration was developed. Instead, the experience relies exclusively on a visual narrative, structured through a sequence of animated images and graphic transformations.

4.3 Storyboard: visual design and user interface

The third stage, the storyboard, provided a visual dimension to the narrative project. The sequence of scenes was defined by identifying the visual characteristics associated with each narrative step. In particular, the design choice was made to reconstruct only the individual rooms addressed in the narrative, rather than the entire domus complex, to clarify the relationship between the digital reconstruction and the actual archaeological context. The avatar was identified with the figure of Medusa, a symbolic element of the archaeological park and the clue is one of her "little snake" that escaped from her hair However, to make the character more accessible and engaging, especially for younger audiences a cartoon-style visual characterization was adopted. The scenes were then organized following the visitor pathway defined by the walkway within the archaeological site and suggested by the sequence of clues.

In parallel with the design of the visual and interactive elements, the graphical user interface (GUI) of the application was also defined. A deliberately minimal design approach was adopted to preserve the maximum visual openness during the mixed reality experience and to avoid intrusive interface elements that could interfere with the perception of the real environment. Within this framework, two main informational elements were introduced. The first consists of the name of the archaeological room currently explored by the user, displayed within a lower information bar, thus contextualizing the narrative without compromising scene readability. The second element concerns a visual feedback system designed to accompany the user's progress through the experience. To this end, the logo of the Archaeological Park, represented by the figure of Medusa, was integrated into the interface. As the user discovers and activates the various points of interest and listens to their associated content, the image of Medusa gradually completes itself, with the progressive addition of the characteristic snakes to her hair, providing an immediate visual indication of the visitor's progression through the experience.

4.4 Animatic: temporal organization of the animated sequences

The final stage of pre-production, the animatic, allowed the animation sequences to be schematized and temporally organized. This step is particularly relevant, as the two informational levels, architectural reconstruction and mosaic decoration, are primarily conveyed through animated patterns (Fig. 2). The first level is introduced through the progressive emergence of the 3D model from the existing archaeological remains. The second one is reinforced through the animation of the scenes depicted in the mosaics, facilitating a more immediate and comprehensible reading of the figurative representations. Specifically, the planned animations involve four principal iconographic subjects. For the Drunken Satyr mosaic, the animation focuses on the four lateral scenes representing birds: a peacock eating cherries, a quail pecking apples, a pheasant eating grapes, and a partridge feeding on pomegranates.

For the Gladiator mosaic, the sequence represents a dynamic combat scene depicting the battle and the moment of victory, embedding symbolic elements of the original composition such as a palm branch, a spit with three crowns, a spear, a metal arm guard (*manica loricata*), and a chariot wheel. For Medusa, visual transitions were structured to start from the original mosaic, transform into Perseus' shield, and evolve into the full narrative scene of the hero holding the severed head. Finally, for Leda and the Swan, the animation within the central square of the artifact represents a thunderbolt transforming into a swan that rests in Leda's arms.

Regarding the second output, the video mapping installation, a series of visual transitions were designed to highlight and illuminate the surviving fragments of the fresco and gradually reconstruct the missing portions. The sequence ultimately reverses the animation process, returning to the original state of preservation and creating a continuous loop suitable for museum display.

5. 3D Digital content production

The first operation carried out during the production phase consisted of a laser scanning survey of the remains of the Domus and of the fresco preserved in the museum.

This operation was necessary to establish a robust spatial reference base characterized by high metric accuracy and geometric consistency. The primary objective of this activity was to obtain a reliable three-dimensional model of the archaeological context, suitable for supporting the subsequent phases of 3D modelling and the development of the Mixed Reality applications.

5.1 3D data survey and processing

The survey design involved the use of Terrestrial Laser Scanning (TLS) technology, through the acquisition of 26 scans strategically distributed across the investigation area. In order to ensure the spatial continuity required for the correct functioning of spatial tracking systems.

The acquisition scheme was structured with a scanning station every 2 meters near the main points of interest and every 3–5 meters in the transition areas. The acquisitions were performed using a Leica RTC360 scanner, operating at the maximum available resolution (3.1 mm at 10 m). Attention was paid to minimizing shadowed areas, ensuring sufficient overlap between scans, and optimizing the acquisition angles, in order to guarantee the completeness and reliability of the dataset (Fig. 3). Alongside the metric acquisition, each scanning station was also accompanied by a 360° panoramic photographic capture, enabling

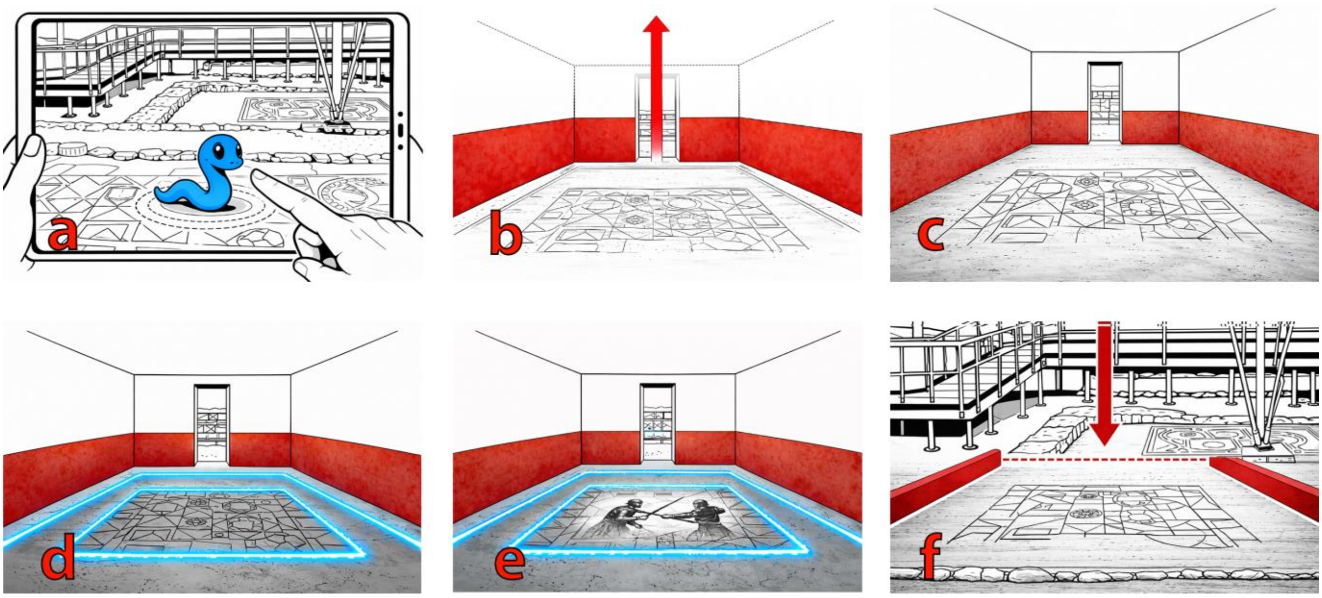

Fig. 2: Animatic: a) selection interaction; b) wall reconstruction; c) room completion; d) mosaic highlighting; e) mosaic animation; f) room dissolve.

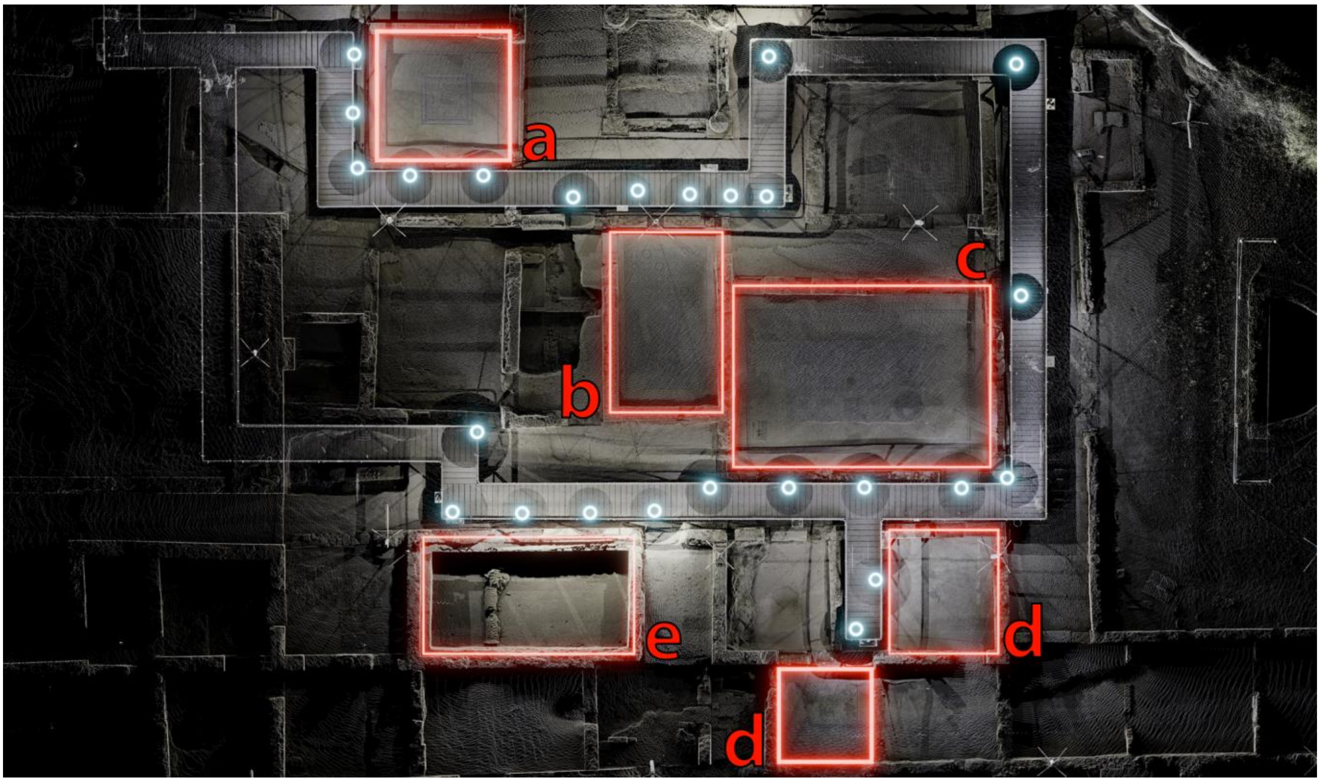

Fig. 3: In blue the capture stations, in red the rooms of interest: a) Tablinium; b) Reception room; c) Triclinium; d) Cubiculum; e) Natatio

the mapping of colorimetric information onto the recorded geometries.

The subsequent phase involved the processing and registration of the acquired data, carried out within the Cyclone CORE software environment. The individual scanworlds were initially aligned through smart align procedures based on the reciprocal visibility between scans and subsequently subjected to a global optimization. This process resulted in a final alignment characterized by an absolute mean error of 0.005 m. The resulting point cloud was then automatically mapped with the equirectangular images, allowing the correct RGB value to be assigned to each point in space. The discrete model obtained was subsequently simplified and exported in .e57 format and finally imported into the Vuforia Area Target Generator software in order to construct the spatial reference infrastructure required for the implementation of the XR application's recognition and tracking system.

The same survey and processing procedure was also adopted for the development of the video mapping installation, with the aim of obtaining a geometric base perfectly corresponding to the existing conditions, necessary for the accurate design and calibration of the projected content. Since the intervention concerned only one wall of the exhibition environment, a scan of the entire room was performed, using the four corners of the space as primary reference points, thus ensuring a correct spatial framing of the projection surface. The acquired data were then subjected to registration and alignment operations in order to obtain a coherent model of the environment. Based on this model, an orthographic image of the wall was generated and used as the basis for designing and adapting the graphic content intended for projection, ensuring a precise correspondence between the physical surface and the projected image.

5.2 3D modelling and XR optimization

Starting from the previously acquired spatial data, the process of three-dimensional modelling of the six environments of the Domus dei Coiedii was carried out within the Blender software environment. The import of the point cloud provided the geometric reference infrastructure, ensuring full metric and spatial consistency between the digital models and the actual dimensions of the archaeological site. To ensure the highest level of scientific accuracy, the reconstructions were continuously subjected to archaeological validation processes, verifying their consistency with existing sources and previous studies related to the complex.

At the same time, considering the performance constraints imposed using Mixed Reality on Android mobile devices, the entire modelling phase was oriented toward the production of lightweight geometries composed of only a few hundred polygons, suitable for real-time visualization within an XR environment.

The subsequent texturing phase involved the use of high-resolution orthographic images to accurately reproduce the chromatic and geometric characteristics of the mosaic pavements, while PBR (Physically-Based Rendering) materials were developed for the architectural elements using Adobe Substance Painter. To meet the hardware requirements of the mobile application, the assets were subjected to an advanced optimization process. The various geometries were merged into a reduced number of meshes, and a complete texture baking process was performed (diffuse, normal, and emission maps), including the pre-calculation of direct and indirect lighting within the RGB component of the materials. This strategy made it possible to simulate realistic lighting conditions avoiding the computationally expensive use of real-time dynamic lighting. The fully optimized scene was finally exported in .fbx format for subsequent integration into the game engine, where it was used to develop the interactive Mixed Reality experience (**Errore. L'origine riferimento non è stata trovata.**).

6. *AI-based 2D content generation*

Within the project, Generative Artificial Intelligence was employed in two distinct but complementary processes: the creation of animated visual narratives based on the mosaics of the archaeological park and the digital reconstruction of the fresco for the videomapping installation. Both applications relied on a workflow combining generative image models, video synthesis models, and traditional post-production tools.

6.1 Generative reconstruction and animation of mosaic narratives

The visual development process followed several iterative phases. Starting with the photographic documentation of the mosaics and the interpretative guidelines provided by the museum direction, the first step consisted of defining an appropriate visual style capable of maintaining coherence with the archaeological context while also producing visually engaging imagery for visitors.

This stylistic research was conducted using the generative image platform Midjourney (Midjourney Inc., 2022). A visual moodboard and a set of style references were progressively developed within the platform. The reference material included both the mosaics from the archaeological site and additional examples of ancient mosaics supplied by the museum direction. By generating numerous images using these references, it was possible to converge

Fig. 4: a) diffuse map with baked lighting; b) final visual result of the 3D model

toward a consistent visual language that could be applied across all narrative scenes.

Once a coherent visual style had been established, the next phase involved the creation of tailored prompts for image generation. This task was supported by a large language model trained to produce effective prompts for generative image systems. Starting from the textual descriptions provided by the museum direction, the narrative content was divided into individual scenes, each corresponding to a specific generated image.

The development process involved extensive experimentation, including iterative adjustments of prompts, visual references, and generation parameters within Midjourney. Additional generative models were also employed for image editing and refinement, particularly Google Nanobanana (Google, 2025) and Flux Kontext (Black Forest Labs, 2025). These tools enabled targeted modifications of the generated images to better align the visual results with the expectations of the curatorial team. Specifically, to prevent AI "hallucinations" or anachronisms, particularly in elements like gladiator armor, the prompt engineering and the generated images were strictly refined under the direct control of the archaeologists. Their specialized knowledge actively guided the use of generative inpainting tools to manually correct any visual inaccuracies, translating archaeological expertise into precise visual constraints and ensuring the historical reliability of the final output.

Throughout this phase, the workflow involved continuous collaboration between the development team and the museum direction. Multiple visual proposals were presented, evaluated, and refined through iterative feedback cycles until a final set of images was approved.

Once the final images representing each narrative scene had been selected, they were used as the basis for the subsequent animation phase.

6.2 AI-based animation of generated scenes

The animation process relied on generative video models capable of transforming still images into short animated sequences. As in the image generation phase, prompt design played a central role in controlling the behavior of the models.

For each image, a detailed description of the intended movement and visual dynamics was prepared and submitted to a language model trained to generate prompts for video synthesis systems. Each prompt was designed specifically for both the scene and the target video model.

Several video generation models were employed during the project, including Kling (Kuaishou Technology, 2024), Hailuo (MiniMax, 2024), PixVerse (PixVerse (AIsphere), 2024), Veo (Google (DeepMind), 2024), and Vidu (ShengShu Technology, 2024). The choice of model depends on the specific requirements of each scene and on the qualitative behavior of the different systems when processing the same input image.

Each generated video clip typically had a duration between five and eight seconds. When necessary, the resulting animations were further processed using Topaz Video AI (Topaz Labs, 2020), which enabled slow-motion interpolation and upscaling. This tool allowed the sequences to be extended up to eight times their original duration while preserving visual coherence.

To complete the production of 2D content through AI-based platforms, a set of video clips was created to serve as the introductory and concluding sequences of the experience. The central element of these visual contents is the guide avatar “Nina”, the small Medusa associated with the Domus dei Coiedii. Starting from a two-dimensional illustration provided as a conceptual reference, the production process involved the generation of animated purely 2D content using the generative AI platform Sora (OpenAI, 2024) (Fig. 5).

Fig. 5: From 2D Concept to Digital Character

Following the same two-dimensional methodological approach, the character of the “little snake”, a key element of the gamification mechanics of the experience, was also generated and animated. The character was subsequently contextualized within a visual environment consistent with the architectural style of the Roman domus, integrating additional animated scenographic video elaborations generated through the Midjourney platform (image of Nina inside the domus). In the subsequent phase, attention was focused on the integration of the audio component and facial animation. To ensure an engaging narrative interaction, the 2D animations were complemented with synthetic voice acting generated through the AI platform Hedra (Hedra Inc., 2024), based on the texts developed during the pre-production phase. The system enabled the synchronization of speech with the facial movements of the character, creating a fluid lip-sync effect.

To further complete the production of the bidimensional content, a post-production, compositing, and video editing process was carried out using the Adobe After Effects and Adobe Premiere Pro suite. In this phase, the individual clips related to the animated mosaics were integrated within the UV space of the textures of the corresponding 3D models, ensuring perfect correspondence between the animated component and the reconstructed mosaic surface. These sequences were also enriched with luminous transition effects, designed to emphasize the appearance and disappearance of the animations and to improve the visual readability of the scenes (Fig. 6).

6.3 Generative reconstruction of the fresco for videomapping

A separate workflow was developed for the digital reconstruction of the fresco used in the videomapping installation. This process combined generative image editing models (Google Nanobanana and Flux Kontext) with traditional digital compositing and refinement operations performed in Adobe Photoshop. Starting from a photographic image of the fresco containing both visible and missing portions, the reconstruction process was guided by textual descriptions, reality based visual references, and specific requests provided by the museum direction. The fresco was divided into multiple sections, each treated as an independent visual element requiring targeted reconstruction. The upper masks were reconstructed starting from the surviving fragments of the fresco and from additional reference images supplied by the museum direction. In the lower section of the composition, the decorative garland was enriched with additional details, and a trophy of weapons was added to the central column in accordance with

Fig. 6: Sequence of the realized and post-produced animations for the mosaic floor

the indications and reference materials provided by the museum direction. The final reconstructed image was the base of the final video used for the video mapping. Also in this case, the video montage was realized in Adobe Premiere Pro, resulting in a sequence specifically conceived to be played in continuous loop during the exhibition experience. The visual narrative follows a gradual progression: first, the edges of the preserved fragments are highlighted; subsequently, the existing remains are illuminated in white to enhance their readability; finally, the missing portions of the fresco are chromatically reconstructed. The sequence concludes by reversing the animation, returning to the original state of conservation and thus creating a cyclical reading between the preserved state and the hypothetical reconstruction (Fig. 7).

this phase, the Area Target component was configured to ensure precise correspondence between the reconstructed three-dimensional model and the digitally acquired archaeological remains. This alignment is a crucial factor for ensuring accurate device tracking and the correct spatial placement of digital content within the real environment. Once the tracking system had been configured, the architecture of the contents, interactions, and animations defined during the previous phases was implemented.

Regarding the structure of the application, in order to optimize performance and ensure efficient management of hardware resources, particularly battery consumption during on-site use, the project was organized into two separate scenes. The first consists of an introductory scene, designed as a lightweight and static interface.

Fig. 7: Sequence of the animations created for the fresco in the museum

7. The App development

Upon reaching the final stage of the development process, the post-production phase, a systematic integration of all 2D, 3D, and audio content with the interactive system and spatial recognition framework required for the Mixed Reality application was carried out. This operation was conducted within the Unity 6 game engine, resulting in the generation of an .apk file for the Android operating system, ready to be installed on the mobile devices provided by the Archaeological Park.

The first step involved the import of all previously developed digital assets, followed by their conversion and compression according to the technical requirements of the Android environment. Subsequently, the packages and SDKs of the Vuforia platform were integrated to implement the spatial recognition system. During

Keeping the application in this state during periods of inactivity prevents continuous use of the camera and AR tracking system, thereby significantly reducing resource consumption. The second scene represents the main experiential environment, within which all three-dimensional models, videos, and multimedia content were integrated and spatially positioned in accordance with the narrative path defined in the earlier design stages.

The dynamic management of interactions and animations was implemented through custom-developed software components. A custom shader was designed to enable the progressive visualization of the reconstructed rooms, controlling the appearance and dissolution of the three-dimensional environments by reading the local coordinates of an animated guide object. The entire sequential logic of the application was instead managed by a central script manager, responsible for orchestrating and synchronizing all system events. This component controls the activation of the user interface elements, the update of the progress indicator, the coordinated triggering of animations, and the playback of audio tracks.

Finally, the same script also manages the automatic restart of the experience once the narrative path has been completed, returning the application to the initial scene and making the system cyclical and immediately ready for a new visitor (Fig. 8).

was not conceived as a purely technological exercise but rather achieved through the implementation of a rigorous methodological framework, articulated into four fundamental and interconnected steps, aimed at ensuring the long-term sustainability of digital innovation.

The first essential pillar of this framework is the scientific digitization of heritage, which was implemented through on-site laser scanning surveys and the subsequent optimized 3D modelling of the ancient architectural spaces. The second step concerns the development of new

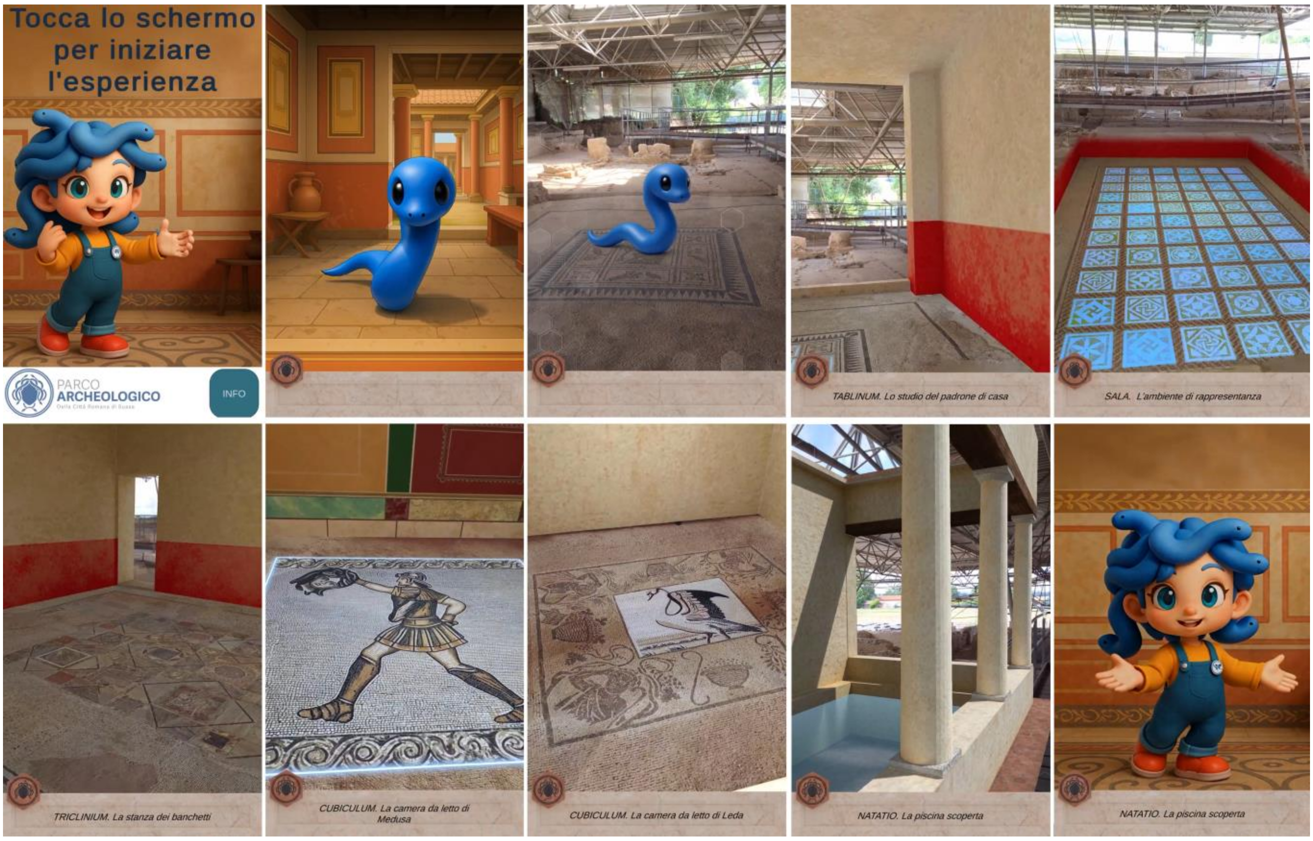

Fig. 8: Final Experience Sequence

8. *Results and conclusions*

Virtual, extended, and immersive experiences applied to archaeological sites offer a broad and diversified range of solutions capable of significantly enhancing awareness, understanding, and accessibility of Cultural Heritage. Within this broader framework, the present research project centered on the Domus dei Coiedii demonstrates how, through a targeted design approach, it is possible to move toward the construction of an authentic "conscious digital cultural heritage" (Clini & Quattrini, 2020) . This ambitious objective

forms of interactive digital engagement. The Mixed Reality application responds to this need by combining the accuracy of archaeological reconstruction with AI-generated narrative content and gamification mechanics. The entire technical design was guided by the objective of creating the simplest and most accessible application possible. The user interface was therefore conceived following a deliberately minimal graphical approach, free of intrusive elements and easy to use. To effectively address the third methodological pillar, namely the development of new professional skills for managing digital heritage workflows, a dedicated training session was organized and conducted directly at the Suasa Archaeological Park. Specifically, before releasing the app to the public, a presentation day was held within a workshop titled "Applied Technologies in the Suasa Archaeological Park and Museum" (funded by NextGenerationEU under the PNRR framework for the capacity building of cultural operators). During the event, particular emphasis was placed on the crucial role of storytelling in digital restitution projects to actively foster user engagement. Furthermore, the application was directly tested by the participants; during the concluding discussion, valuable feedback, appreciations, and suggestions for potential improvements were collected. This crucial moment of technology transfer provided cultural operators and staff with the practical skills required to manage the introduced innovation, ensuring appropriate assistance to visitors and supporting the long-term sustainability of the project beyond its experimental validation phase.

Finally, the fourth element of the methodology involves the measurement and monitoring of public reception and engagement. User Experience (UX) tests will be conducted directly on-site during the official opening of the archaeological park for the summer 2026 season. These evaluation sessions will make it possible to analyze the actual behavior of visitors in situ, collect valuable feedback on the usability of the interface, and gather both quantitative and qualitative data necessary to assess the real educational and experiential impact of the application. In this way, the study will contribute to demonstrating how XR technologies can successfully redefine the relationship between the visitor, historical knowledge, and the museum institution.

Demonstrating the effectiveness of this approach in cultural communication, the project gained significant international recognition, winning the first prize in the audiovisual and multimedia cathegory at the AVICOM festival, as best work for education and mediation cathegory, promoted by ICOM during the conference held in Dubai in November 2025.

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