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ENHANCING ONSITE AND ONLINE MUSEUM EXPERIENCE THROUGH DIGITAL RECONSTRUCTION AND REPRODUCTION: THE RAPHAEL AND ANGELO COLOCCI TEMPORARY EXHIBITION

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Abstract

Leveraging extended reality technology, digital reconstruction, and reproduction of cultural heritage can enable effective solutions to enhance museum experience. Particularly, this paper focuses on virtual reality as a tool to support both onsite and online visits of a temporary exhibition dedicated to Raphael and Angelo Colocci. We present an immersive VR experience of the School of Athens. Within the digital reconstruction of its architecture, two actors provide descriptions of its features and significance, blurring the line between real and virtual. Furthermore, to ensure that visitors can continue to explore the exhibition even after its closure, we developed a virtual tour. Taking advantage of panoramic images and 3D digital replicas, it continues to convey the same cultural contents, preserving the essence of the exhibition. In conclusion, we conducted evaluations of both the experiences to assess their effectiveness and gather insights for further enhancements.

Keywords

3D reconstruction, digital replica, virtual reality, virtual tour, temporary exhibition

1. *Introduction*

The reproduction of a Cultural Heritage (CH) carries the same cognitive value as the original. Indeed, throughout history, the transmission of human knowledge has relied on the production of copies, focusing sometimes on the content, sometimes on the form, and sometimes on both the form and content. Digital replicas thus seamlessy integrate into this tradition of knowledge dissemination. However, compared to solutions adopted in the past, these digital copies offer the unique advantage of transmitting both the object and its narrative simultaneously. Consequently, the way we experience the digital replica becomes pivotal, so, the choice of the appropriate technological device and its usage play a crucial role in delivering the most authentic representation and effective storytelling of the cultural asset.

Museums are progressively adopting diverse approaches for sharing and communicate cultural content. They are harnessing digital technologies to generate digital representations and narrative strategies addressed to a wide range of audiences. Particularly, eXtended Reality (XR) offers the possibility to blend different media and enhance user interactions, facilitating the dissemination of scientific research on CH sites and museum collections in immersive and captivating ways for different audiences. The advantages of XR solutions extend to the representation, interpretation, and communication of CH, providing solutions that support analysis, research, and enhance cultural accessibility. Furthermore, XR experiences can be designed to provide both onsite and online experience, a crucial aspect that allows museums to enhance their exhibitions and reach a broader spectrum of visitors. The work presented aligns with this context by showcasing the digital solutions employed in the exhibition dedicated to Raphael and Angelo Colocci, which took place at Palazzo Pianetti in Jesi, commemorating the five-hundredth anniversary of the artist's death. Leveraging a range of technologies and a narrative approach influenced by techniques and languages from the realm of entertainment, the exhibition delivered an experience that structured a path to knowledge. This path was primarily built upon the meticulous three-dimensional reconstruction of

the renowned architectural space depicted in the School of Athens. Moreover, the digitization of the exhibition itself ensures ongoing accessibility. Indeed, a virtual reproduction of the phisical setup continues to disseminate the same cultural content after the exhibition's closure.

2. *Background*

From the 1970s onwards, the development and proliferation of digital technologies and computer graphics have triggered an inexorable revolution in all disciplinary sectors, including those related to CH (Brusaporci & Trizio, 2013). From the earliest experiments in the field of archaeology (Forte & Siliotti, 1997), it has been possible to observe an increasingly widespread use of 3D modeling and visualization tools, leading to the most recent international charts and European programmatic plans (European Union, 2020).

Digital technology has changed the way cultural institutions interact with their audiences. Particularly, museums have harnessed digital visualization methods to enrich their storytelling approaches and engage with visitors, whether through online platforms or in-person visits (Mezzino, 2023). Furthermore, virtual, and physical dimensions complement each other; and increased online visitors often lead to more onsite visits (Garlandini, 2021).

In this scenario, XR tools have proven their effectiveness in narrating and evoking both the tangible aspects and intangible significance of CH (Bekele, Pierdicca, Frontoni, Malinverni & Gain, 2018). Particularly, Virtual Reality (VR) can provide CH virtual representations along with different related information. Thus, taking advantage of both 3D reconstructions (Carrozzino, Evangelista, Brondi, Tecchia & Bergamasco, 2014) and reproductions (Apollonio, Fantini, Garagnani & Gaiani, 2021), it is possible to provide cultural contents in a more user friendly and effective manner.

2.1 3D reconstruction of painted architectures

Within the broad field of CH applications, a case of particular interest is the application of these technologies to two-dimensional visual arts such as painting. These technologies enable the extension of traditionally 2D representation into a navigable 3D dimension, offering new and intriguing insights not only from the perspective of appreciation but also in terms of the study of the artwork itself. These tools allow for a scientific investigation of the artwork's creation, bridging the gap between the study of perspective accuracy and the artist's compositional choices, and expanding interpretative possibilities through the three-dimensional representation of the non-visible parts of the depicted scene (Criminisi, Kemp, & Zisserman, 2005).

Numerous studies involve 3D reconstructions of architectures based on two-dimensional representations such as engravings, drawings, or paintings to achieve a deeper understanding of the artwork, not only by scholars but also by the general audience (Apollonio & Foschi, 2022; Merlo & Bartoli, 2021; Ciammaichella, 2019; Clini et al., 2019; Carrozzino et al., 2014; Lourakis et al., 2007).

2.2 *Digital replicas of Cultural Heritage*

Reality-based models facilitate a deeper understanding of CH and provide enhanced accessibility (García-León, Snchez-Allegue, Peña-Velasco, Cipriani & Fantini, 2018).

As presented in (Valzano & Mannino, 2020), a scientific digitization of CH fosters new forms of representation and experience able to stand the test of time. Moreover, by mixing techniques of 3D reproduction and video shooting, it is possible to enable effective virtual journeys and guided tours (Valzano, Negro & Lucarella, 2019).

Focusing on 3D reconstruction methods, digital photogrammetry has demonstrated its effectiveness as a valuable tool for documenting and representing different cultural assets (Bagnolo, Argiolas & Bellumori, 2021; Ciammaichela & Liva, 2021; Zampieri, Baldoni, Garagnani, Gaucci & Silani, 2021; García-León et al., 2018). In (Apollonio et al., 2021) digital replicas of CH are presented as one of the most promising innovations for museum exhibitions. Moreover, the paper introduces a robust, easy-to-use 3D digitization and visualization workflow based on low-cost widespread devices.

Regarding digitization, the steps of the proposed workflow are the same followed for the digital replicas presented in this paper: image pre-processing, automatic 3D model construction, highpoly model alignment and scaling, lowpoly model processing, normal and diffuse color mapping.

2.3 Digital tools for onsite and online museum experience

Amid the widespread global effects of the Covid-19 pandemic, the containment measures implemented during the health crisis resulted in the full shutdown of numerous cultural sectors or restricted access to them for only a limited audience. Now, more than ever, our access to CH presents us with the dual challenge of balancing physical presence and remote experiences (Clini & Quattrini, 2021).

Having the capability for interactive manipulation opens a spectrum of possibilities for presenting cultural contents. These possibilities span from educational applications to advanced research endeavors and even tourism proposals, among other uses. This functionality is highly significant because it ensures accessibility to a wide audience. Additionally, it empowers users to take an active role, which is not only more engaging but also more fulfilling for them.

Multimedia installations inside museums can guide the visitors in understanding and reading the collections, supporting new communication projects, and enhancing CH (Ciammaichella & Liva, 2021). Moreover, they can enable to display fragile artifacts, e.g., ancient manuscripts. exploiting their digital replicas (Gaiani, Garagnani & Zannoni, 2022). Focusing on immersive VR, it has proven to be an effective technology to enable experience of virtual reconstructions of architectural structures and historical sites. (Vučković, Stanišić & Simić, 2017) presents a VR experience of the reconstruction of Nikola Tesla's laboratory. The research was carried out in cooperation with the Nikola Tesla Museum in Belgrade, Serbia. The ArkaeVision project seeks to introduce a novel approach to experiencing cultural heritage by enhancing user engagement and providing a culturally qualified user experience (Bozzelli, Raia, Ricciardi, De Nino, Barile, Perrella, Tramontano, Pagano & Palombini, 2019). In (Clini et al., 2022) is presented a VR experience of an archaelogical site. Thanks to a VR headset, visitors can explore the roman theater both in its current form and as it was in the first century AD.

Concerning online experience of museum collections, numerous are the possibilities for configuring web pages as 3D models consultation portals (Bagnolo et al., 2021). (Camerota, 2021) highlights the digitization efforts of the Galileo Museum, presenting two thematic digital libraries conceived as environments for research and scientific exchange between scholars, and two virtual exhibitions of historical documents.

In the context of online virtual experiences of museums exhibitiona the Virtual Tour (VT) has become a widely adopted solution, both among internationally renowned museums and local ones (Le Gallerie degli Uffizi, 2020). For instance, the Google Arts & Culture platform (formerly known as Google Art Project) offers a several VTs in which users can explore galleries of cultural partners involved in the project by navigating spherical panoramas (Proctor, 2011). Bonacini (2015) examined the significance of this initiative, highlighting the need for additional content that can enrich the cultural experience offered to users. A more interactive solution is presented, in (Angeloni, 2023), where a VT for experiencing a museum collection is enriched with gigapixel images of paintings and three-dimensional models of statues and architectural elements of the historic building housing the Civic Art Gallery. Evaluating the effectiveness of these new forms of cultural experience is crucial, as demonstrated in Resta et al. (2021), where the experience offered in the VT of the Troya Müzesi archaeological museum in Çanakkale, Turkey, is assessed.

3. Research aims

This research utilizes the case study of the exhibition dedicated to Raphael and Angelo Colocci to explore digital solutions supporting both onsite and online museum experience.

Specifically, VR is employed within the physical exhibition setup, enabling visitors to virtually step into the world of the School of Athens (Clini et al., 2022)[1]. This technology provides an opportunity to experience the fresco even in its physical absence. Furthermore, the 3D reconstruction of the painting is combined with video footage featuring actors portraying two of the depicted characters, creating a more immersive and engaging experience for visitors.

Given that this case study pertains to a temporary exhibition, another objective of this research was to devise a virtual means of ensuring ongoing accessibility. To achieve this, high-resolution spherical panoramas of the exhibition,

[1] The present paper is an expanded and enhanced version of (Clini et al., 2022), incorporating substantial refinements and significant developments that extend and enrich the previous contribution.

images, 3D models of the artworks and artifacts on display, as well as expert-contributed texts and audio, are integrated into a VT; a solution to offer an online experience that allows for continued virtual visits to the exhibition. Finally, UX tests were carried out to assess their effectiveness and gather insights for further enhancements.

4. *Raphael and Angelo Colocci. A digital exhibition to celebrate the fifth centenary of the artist's death*

Promoted on the fifth centenary of Raphael's death but set up in 2021 due to the COVID-19 emergency, the exhibition aimed to illustrate the figure of Angelo Colocci (1479-1549), a little-known humanist to the general public who had connections with Raphael and shared ideas and interests with him. It was probably his bond with Agostino Chigi that facilitated the meeting between the two, resulting in a profound intellectual relationship that led Raphael to want Colocci by his side in the attempt to edit Vitruvius' De Architectura and, more importantly, to draw direct inspiration from his extensive cosmological studies to give life, form, and color to one of his greatest masterpieces, the Vatican Stanza della Segnatura (Mangani, 2018).

The exhibition offered an interpretative journey into the role played by Angelo Colocci in Rome within the Roman Academy, where he was a prominent figure throughout the first three decades of the 16th century. The focus addressed was his relationship with Raphael, narrated along the exhibition path through original documents and, most notably, through the three-dimensional reconstruction of the School of Athens, made accessible through 3D printing and VR, with the aim of immersing visitors in the spirit of the Rome of the Popes and the cultural environment of the 16th century, a prolific century for the arts (Fig. 1).

5. *From the study of perspective to the 3D reconstruction of the School of Athens*

To correctly understand the process of reconstructing the architecture of the School of Athens, it is essential, as a preliminary step, to analyze how Raphael designed its architectural, perspective, and scenic layout. At the heart of these operations is the desire to represent an imaginary architecture, not real or existing, but capable of "deceiving the eye, satisfying the intellect, and moving the heart", as Francesco Algarotti wrote in the late 18th century. The famous central-plan temple with classical forms and decorations, therefore, appears as an ideal space, dominated by the pursuit of pure compositional forms like the circle and square in line with the ideals of Renaissance humanism (Fig. 2).

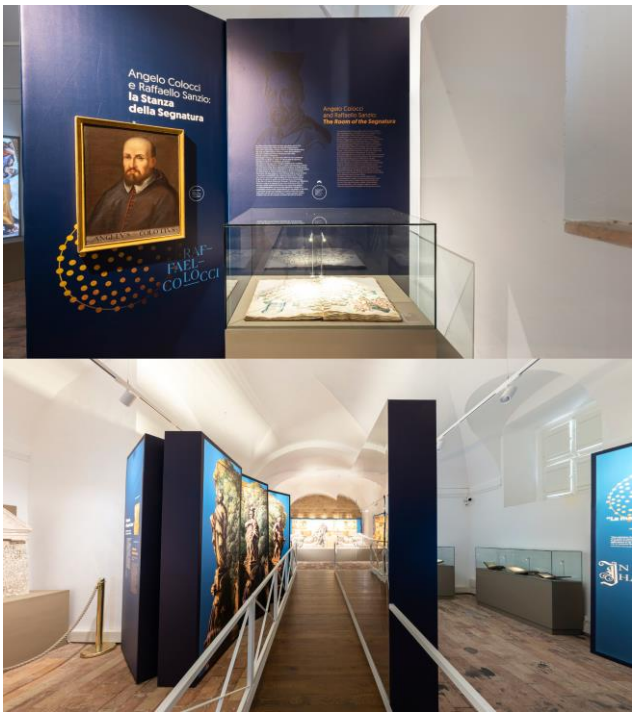

Fig. 1: View of the exhibition set-up.

Given these premises, the representation of the architecture aims to identify a perfect and allegorical stage set. For this reason, the digital reconstruction has been conceived as an act of critical interpretation, aiming not to provide an exact representation of what is observable within the fresco but rather an interpretation focused on achieving a "true" design, one that is believable, real, and complete in all its parts. These characteristics are central for the immersive enjoyment of both virtual and physical spaces through 3D printing. So, it was necessary to conduct a preliminary study of the fresco in order to obtain a comprehensive planimetric representation of the architecture to be used as the basis for 3D modeling. Starting from the high-resolution 2D digitization of the fresco provided by the Vatican Museums, the first step involved the analysis of the perspective elements. This study followed a perspective representation technique presumably close to what Raphael used, as described in (Spagnesi, Mandelli & Fondelli, 1984), leading to the identification of a geometric system

based on the shape of an isosceles triangle with a base equal to the height, corresponding to the cubic space above the horizon line (Fig. 3). All essential information for determining key measurements, such as the position of measurement points, the distance from the viewpoint, and the width of the optical cone, falls within this system. This scheme, developed in its three-dimensional dimension, serves as a spatial guide, with its minimum unit forming the basis for the proportioning of all major architectural elements (central nave-dome).

By relating the grid system to the dimensions of the depicted human figures, it was possible to provide a metric and proportional dimension to the layout. This assumption does not provide an objectively certain measurement but allows for the maintenance of proportional relationships between architecture and humans, thereby obtaining an initial partial planimetric framework.

The next step involved the regularization of the obtained planimetry following an analysis and interpretation process that addressed clear irregularities attributed to the painterly stroke (graphic error) and compositional choices. The most significant irregularities concerned the mutual dimensions of the pilaster-niche system of the naves and the impost of the high drum. The first irregularities, at least from a planimetric perspective, were regularized by averaging the dimensions obtained. This was because a proportioning based on the study of architectural treatises (Vitruvian orders) would have entailed a substantial modification in the proportioning of the macro-elements identified in the grid system previously described. The second critical issue pertained to the static interpretation of the architecture, namely, the representation of the pendentives-drum-dome system. Starting from the bottom, the junction between the longitudinal

Fig. 2: Raphael, La Scuola di Atene, 1509-1511 approx., Musei Vaticani, Città del Vaticano.

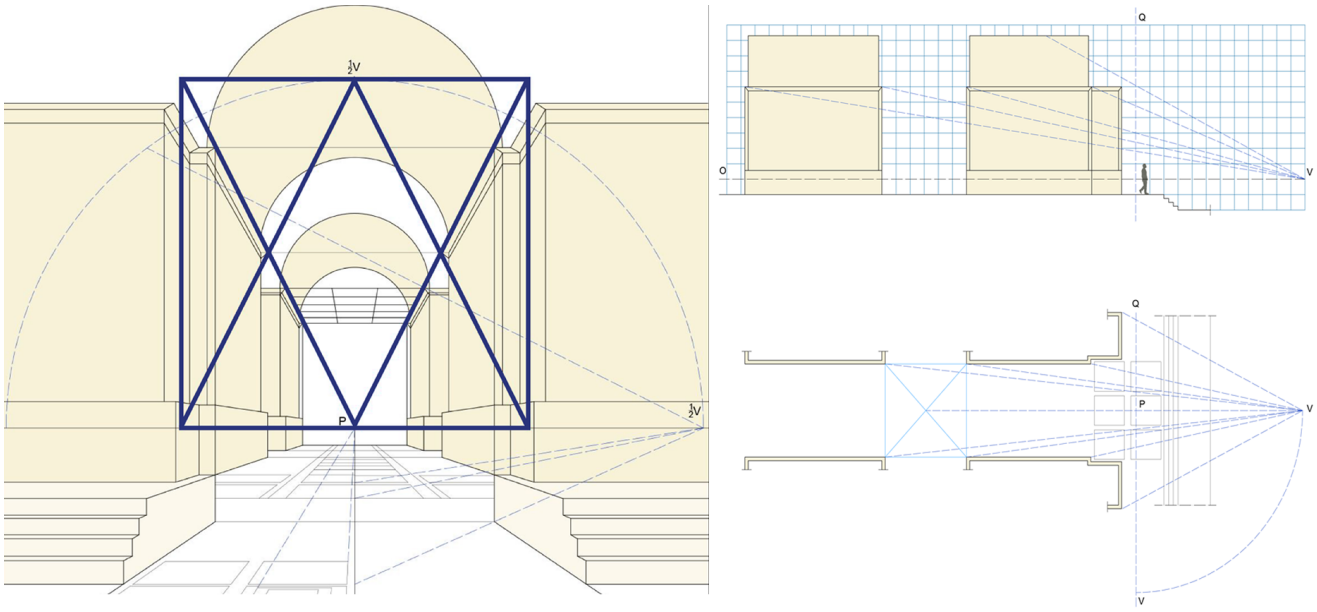

Fig. 3: Perspective and proportional scheme of the architecture depicted in the fresco.

and transverse nave occurs at a right angle of 90°. This geometric arrangement is not statically confirmed at the upper level, specifically in the pendentives supporting the high drum, which, to be corrected, should have a triangular configuration, as is the case with the Church of Santa Maria delle Carceri in Prato. Instead, they have a wide trapezoidal shape. To remedy this inconsistency, a 45° inclined wall connection element was introduced between the naves. This element provides a correct impost for the trapezoidal pendentives, as seen in the current Basilica of St. Peter in Rome. This solution facilitates the maintenance of compositional proportions between the reconstruction model and the fresco while also allowing for the easier incorporation of decorative medallions. This configuration was suggested by the analysis of a preparatory cartoon, now housed in the Pinacoteca Ambrosiana in Milan (Zanchettin, 2018).

Having obtained a coherent planimetric development of the structural macro-elements, it became possible to proceed with the reconstruction of the non-visible parts, resulting in a complete architecture. An accurate analysis was conducted of the sources that inspired Raphael in defining the formal and decorative features of his architecture: his study of antiquity, evident in the use of coffered vaults typical of Roman

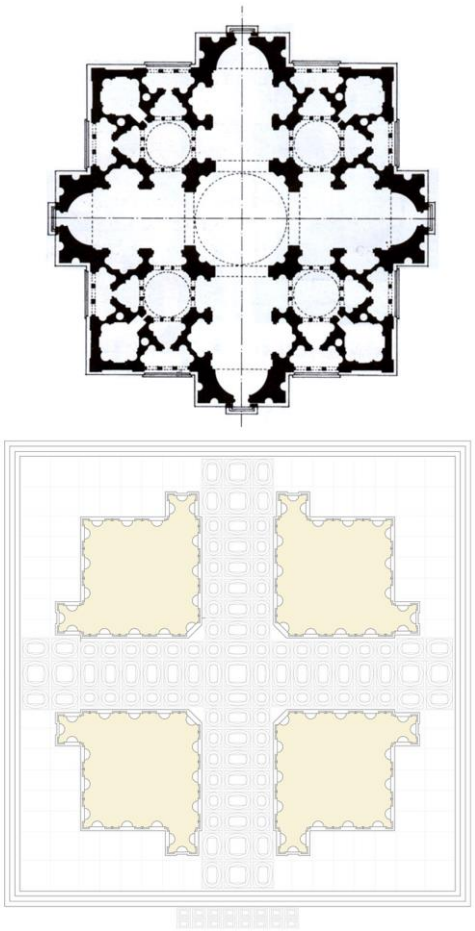

Fig. 4: Comparison between the floor plan of Bramante's St. Peter's Basilica and the reconstructive hypothesis of the School of Athens.

architecture (Pantheon and Basilica of Maxentius), and his interest in contemporary themes. The original Greek cross layout with a central dome, very close to Bramante's project for St. Peter's in Rome (Fig. 4) (De Rosa et al., 2001), was thus completed, featuring a coffered vault like the one of the Pantheon. Connection with Bramante's architecture also helped define the characteristics of the drum, including the insertion of a Serlian motif, as seen in the design used for the choir arch of the Church of Santa Maria del Popolo in Rome.

The external surfaces were completed by analogously following the compositional scheme observable in the fresco, while the elevation closure of the building was determined by duplicating the decorative system of the lower order but without niches. The height of the latter was determined starting from the intrados, including the barrel vault frame of the central nave.

After the coherent and complete planimetric development in place, the decorative profiles of the pedestal, pilaster base, shaft, capital, and entablature were indentified. For each object, a sample element on the fresco was selected and broken down into its individual parts such as torus, cyma reversa, scotia, ovolo, echinus, abacus, etc., and then sought a concordance with the descriptions found in treatises and realised works probably known to Raphael. As can easily be guessed, no direct correspondence with the treatises was found, but this comparison allowed us to give a proportional order to the reconstruction, searching for the most similar model in terms of the compositional succession of elements, and to modify it, making it correspond with the Urbino artist's representation.

Based on the planimetric development and decorative profiles, the 3D modeling was executed within the Blender software (Fig. 5), while the texturing process was carried out using Adobe Substance Painter, resulting in PBR Material textures as output (McDermott, 2018). Regarding the lighting system, an HDRI image was used, with adjustments made to its intensity and directional lighting to achieve the same visual rendering as the fresco. The representation of the architectural scene was completed by adding bas-reliefs and statues, which were isolated from the fresco, and normal maps were generated using Adobe Photoshop to incorporate surface micro-details.

Upon concluding the 3D reconstruction process, the triumphal arch visible in the central background of the fresco was added. The initial

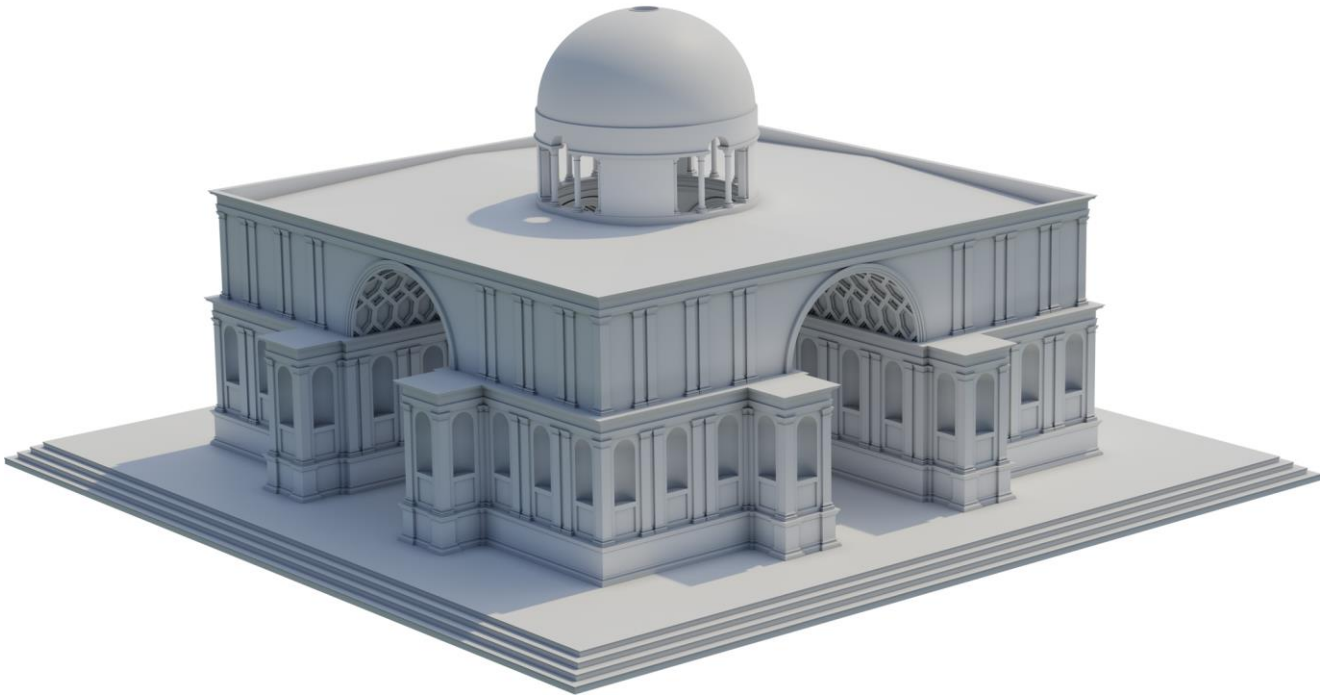

Fig. 5: Perspective view of the 3D reconstruction of the School of Athens.

planimetric study allowed for the deduction of its position, dimensions, and decorative elements. Thanks to the 3D modeling of the entire layout, the dimensional and perspective viewing relationships between the temple and the arch were verified. The model thus obtained served as the basis for animations and renderings of the virtual experience and for 3D printing. Regarding the latter aspect, only a quarter of the entire structure was selected and edited to obtain a manifold model, meaning it was free of holes or penetrations, which is crucial for successful 3D printing. The obtained portion was exported in STL format and imported into slicing software to create a model divided into print layers. The PLA filament printing technology was chosen, as it is cost-effective and easy to manage. A Lab65 H3 printer with a 0.4mm diameter nozzle was used. Each individual quarter was printed three times to obtain a partial model suitable for the enjoyment of the interior space, resulting in a 1:50 scale model (Fig. 6).

Fig. 6: View of the 3D model within the exhibition set-up.

6. *The VR experience: an immersive journey within the School of Athens*

To offer visitors a novel experience of the School of Athens, an immersive digital storytelling has been structured, aimed at blurring the distinction between the real and virtual worlds. Using a VR headset, visual and auditory perception have been combined to achieve a complete immersion in the virtual reconstruction of the painting, complemented by the presence of characters guiding visitors in their exploration. As shown in (Fig. 7), the actors' performances were recorded on a green screen, edited, and integrated into various scenes composed of panoramic images obtained from the 360° rendering of the three-dimensional model of the School of Athens. Representations of the philosophers were also added to the third scene, following the creation of two-dimensional animations to enhance the dynamic nature of the experience, emphasizing the gestures depicted by Raphael.

From a technological standpoint, the immersive journey with Raphael and Angelo Colocci inside the School of Athens was developed using the game engine Unity, particularly to be used on the Oculus Quest 2 headset. Once the headset is worn, the experience automatically starts, allowing the user to select their preferred language or subtitles using hand gestures. When the headset is removed, the experience is programmed to reset so that the next user will always find themselves in the language selection environment, avoiding conflicts between visitors.

The storytelling is divided into four parts: during the introduction, the user finds themselves inside the Stanza della Segnatura, where they can observe the School of Athens alongside other frescoes by Raphael; in the second part, the user enters the painted space, reaching beneath the depicted dome behind the philosophers, where they meet Raphael and Angelo Colocci, portrayed by two actors, who introduce themselves and explain the allegorical meanings of the architectural space; in the third part, the user stands before the grand temple, and the philosophers, introduced by the two actors, gradually appear, populating the fresco; in the final part, through a gradual transition from the three-dimensional reconstruction to the view of the fresco, the user returns to the physical space of the Stanza della Segnatura (Fig. 8).

7. *A digital tool to keep the temporary exhibition accessible*

To preserve the possibility of visiting the temporary exhibition after its closure, a virtual representation was generated. So, the exhibition spaces were documented by capturing 360° images, with careful consideration given to the choice of shooting points to ensure proper visualization of the various installations. Each of the 9 spherical panoramas required for a comprehensive representation of the exhibition spaces was created from 18 individual shots taken using a digital camera mounted on a panoramic head. These shots were then processed using PTGui software to create individual equirectangular image with a size of 16.384 x 8.192 pixels.

Fig. 7: School of Athens virtual scene. Actors on green screen positioned among philosophers.

Fig. 8: Frames from the four parts of the VR experience on which its storytelling is structured.

Concerning the artifacts that were displayed within the temporary exhibition: the funerary Stele of the Aebutii, the Menologium Rusticum Colotianum, and the Sleeping Ariadne, they underwent a 3D reconstruction process involving the following stages: image captuirng, image pre-processing, automatic 3D reconstruction, 3D meshes post-processing, retopology, and texture baking for normal and diffuse color mapping. The image capturing phase was carefully planned, to be carried out without moving the objects from their positions in the exhibition. To ensure proper lighting for subsequent three-dimensional reconstruction, four LED panels were used instead of the lighting system originally intended for the exhibition. The choice of lens focal length was based on the expected level of detail, considering the different geometric characteristics of the objects and the shooting distance: a 90 mm focal length lens was chosen for the funerary Stele of the Aebutii and the Menologium Rusticum Colotianum, while a 35 mm focal length lens was chosen for the Sleeping Ariadne. The GSD is lower then 1 mm both for the Sleeping Ariadne, and the other two artifacts, providing and adequate level of detail to document the engravings on their surfaces. The three-dimensional reconstruction of the objects was then obtained from the images using the standard processing process based on Structure from Motion Dense MultiView Reconstruction algorithms. The resulting models were optimized for online use, reducing the level of detail in the geometries without compromising visual quality thanks to the texture baking of normal (Fig. 9).

Using these digital representations of spaces and exhibited objects, a virtual tour (VT) of the exhibition was created using Pano2VR software. Through clickable hotspot connections between the different panoramas, users can explore the exhibition spaces in a manner like what is offered by VTs available on the Google Arts & Culture platform. The user interface and interactions developed for this VT also allow users to access additional content by simply clicking on objects of interest: brief textual descriptions are provided for paintings and volumes, while 3D models are available for the artifacts and for the reconstruction of the School of Athens. Moreover, by entering the hall that was dedicated to the VR experience, the user starts a 360° video reproducing it. Leveraging the same exhibition setup and narrative choices as those used in the physical exhibition space, the VT continues to convey the content presented in the various installations through a completely virtual and interactive experience (Fig. 10).

Fig. 9: Digital replicas of the artifacts on display.

8. *Conclusions*

Virtual experiences in museums and cultural sites offer a wide range of solutions capable of enhancing awareness and understanding of CH.

Drawing some general conclusions from the UX evaluation of both presented virtual solutions, which was carried out using questionnaires and direct observations, we find the following insights. Regarding the immersive VR experience for exploring the 3D reconstruction of the School of Athens, a significant majority of visitors (91%) engaged with the digital VR movie, even though it was also available on a screen for those who preferred not to use the VR headset. Observations revelead that only a small percentage (6%) required assistance from museum staff, primarily to initiate the experience. This issue was mostly related to the low lighting in the room, which impacted the headset cameras' ability to detect hand movements.

Visitors expressed a strong appreciation for the storytelling and the immersive quality of the VR experience. However, they found the interaction within the virtual environment to be rather limited, as users were not granted the freedom to explore the virtual space as they desidered. The choice to offer a seated VR

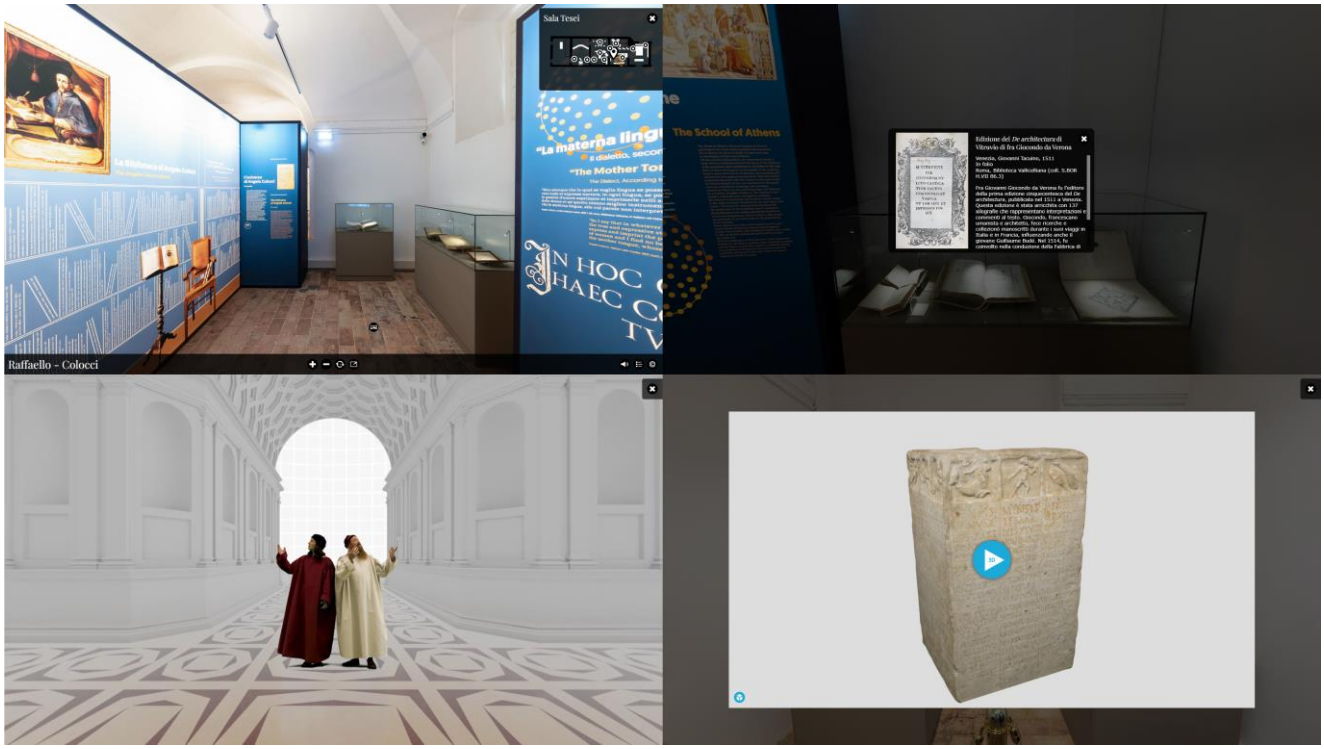

Fig. 10: The VT experience of the exhibition.

experience was influenced by the museum's exhibition layout. To further enrich the visitor experience, there is potential for the development of a more interactive experience, possibly incorporating elements of gamification related to the narrative guided by Raphael and Angelo Colocci.

The VT of the temporary exhibition was also subjected to evaluation. This UX evaluation test was based on the four experiential dimensions proposed by (Pine & Gilmore, 1998), which have previously applied in the museum context by (Radder, 2015). Here, they were specifically adapted for a VR experience encompassing learning, entertainment, immersion, and aesthetics. The results, obtained from a sample of individuals who did not physically visit the exhibition, underscored the effectiveness of the representation offered by its digital replica. This representation faithfully recreated the exhibition halls and the displayed artifacts. From an educational perspective, the scores demonstrate that the virtual experience stimulates user curiosity and provides the opportunity to convey content at various levels of depth.

Despite their distinct characteristics, both solutions emphasize the crucial role of digital representation techniques in enriching CH experience. These techniques facilitate varying levels of interaction with digital objects and multimedia content, ultimately working towards improving accessibility, both in terms of cultural engagement and physical access, within a museum exhibition.

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