The VR visualization of Giovanni da San Giovanni's Chapel

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Abstract

The Chapel, painted in 1621 by Giovanni Mannozzi, better known as Giovanni da San Giovanni, is a work housed at the Academy of Fine Arts in Florence. It comprises a cycle of paintings contained within a space measuring only a few square meters. This piece is an original work, one of the few and oldest preserved at the academy, which prompted the decision to digitize it and develop a digital visualization system for the architectural environment and the frescoes it encompasses.
This initiative facilitates access to the Chapel via Virtual Reality, allowing visitors to explore the space in a first-person perspective freely. A Virtual Reality view was chosen to align with the conceptual design of the Chapel - a small space almost entirely covered in frescoes, naturally lending itself to immersion, which is intrinsic to its design.
The application was developed as part of the AMABAFi (Multimedia Archive of the Academy of Fine Arts in Florence) project, which seeks to establish a systematic standardized methodology for the digitization, preservation, and dissemination of the artistic heritage of the florentine Academy.

1. Introduction

The project presented herein is part of the broader digitalization initiative of the Academy of Fine Arts in Florence, leading to the creation of AMABAFi (Multimedia Archive of the Academy of Fine Arts in Florence). The concept for the archive stems from the doctoral research of Giovanni Grimaudo (Grimaudo et al., 2025).
Beyond standard archiving and the scientific visualization of individual works, there is a clear imperative to present these assets in an interactive and immersive format.
Virtual Reality (VR) has been identified as a primary modality for this purpose, following successful implementation in the virtual exhibition *Il Culto del Bello. Antonio Canova, Giovanni degli Alessandri e l'Accademia di Belle Arti di Firenze*.
In this specific context, VR is ideally suited to the case study: the Chapel of Giovanni da San Giovanni. Originally conceived as a private, immersive space for individual visitation, the chapel's architectural intent is mirrored by the VR experience. Furthermore, the site is currently inaccessible and remains relatively obscure, providing additional justification for producing a digital version for remote accessibility.
This paper is structured as follows: After providing the historical and artistic contextualization of the site, a detailed analysis is presented regarding the selection of this work for VR experimentation at the Academy of Fine Arts in Florence.
The subsequent section describes the photogrammetric acquisition and processing workflow. The primary high-resolution model has been archived as a master copy for scientific study (available upon request), while an optimized version serves as both the consultable object on the online platform and the reference environment for the VR experience.
The focus then shifts to the software development of the application, with particular emphasis on User Experience (UX). Finally, the paper concludes with the credits – showing the division of labor within the research group – and the references.
It should be noted that the AMABAFi project is currently ongoing; consequently, while the VR application is functional, it is slated for a series of more extensive user tests already in the planning phase.

2. Historical and artistic context

In a cultural landscape increasingly marked by privatization processes and commercial logic, artistic heritage requires new strategies capable of reaffirming its civic and social function. The research conducted by the working group of the Academy of Fine Arts in Florence, presented here, focuses on the historical and digital revaluation of the centuries-old Florentine Institution's artistic heritage, combining technical expertise with art-historical knowledge.
Founded in 1784 by Grand Duke Peter Leopold, the Academy of Fine Arts in Florence originated from the separation from the earlier Accademia del Disegno – the first art academy in the world, established by Giorgio Vasari in 1563. As early as its first inventory, compiled in 1785, the Academy already possessed an extraordinarily rich collection, comprising approximately four hundred objects and artworks of various scales and typologies. This corpus included a significant number of statues, plaster casts, and models, alongside a wide variety of other artistic artifacts, paintings, prints, and even frescoes, reflecting the educational role of this Institution, which was central to academic training and artistic transmission between the late 18th and 19th centuries.
Specifically, this paper will analyze the so-called Chapel of Giovanni da San Giovanni. Located within the premises of the former convent of San Matteo – now part of the Academy of Fine Arts of Florence complex – it represents a significant episode in the production of Giovanni Mannozzi, known as Giovanni da San Giovanni (1592–1636). The space, though small in size[1], is entirely decorated with frescoes and is generally dated to the first two decades of the seventeenth

1 The dimensions are: 2.68 x 3.57 meters, with a height of 5.10 meters at the highest point of the vault.

century, a period when the artist was consolidating his stylistic signature (Acanfora, 1998).
Despite being relatively little-known compared to the artist's other public commissions, the chapel plays a pivotal role in the development of Giovanni's language, offering a unified space where the decorative apparatus, painted architecture, and sacred narrative integrate into a visual continuum (Bellesi, 2009).
The overall effect is that of a scenographic box capable of blurring the boundaries between the physical and figurative environments. It anticipates Baroque solutions that, if not imposing, at least suggest a reflection on the very meaning of immersive virtual reality.
It should be noted that this painting was not originally located within the Academy building; rather, it was relocated here in 1786[2] following its detachment (*strappo*) from its original position in the so-called *Giardino della Crocetta* (Crocetta Garden). As the garden of the Monastery of the Crocetta (Fig. 1), this was the initial site of the small chapel intended for Maria Maddalena – the infirm daughter of Ferdinando I de' Medici and Christina of Lorraine – who was secluded there in 1621 (Bellesi, 2017).

Figure 1: The two historic locations of the opera.

Once moved to the Academy, the chapel became part of the spaces formerly dedicated to the School of Sculpture, which are now used by the Set Design (*Scenografia*) department. Only recently has it become visible from the outside once again, thanks to a glass panel that replaced the thick curtains that had shrouded it for more than a century.
Unfortunately, however, the site where the original centering was reconstructed is currently not freely accessible[3], either to students or professors, let alone the general public. This was one of the primary motivations behind the development of the software discussed here.
The centerpiece of this decorative program is the refined mural altarpiece depicting the Rest on the Flight into Egypt, recognized by critics as one of the artist's most prestigious and accomplished works (Fig. 2).
Giovanni da San Giovanni interprets the sacred episode through a lens of humanization and everyday life – a stylistic hallmark that aligns perfectly with the Tuscan artistic tradition which, since the Renaissance, has favored themes of familial affection and elegiac narrative.
The composition unfolds outside a rural farmhouse, immersed in an idyllic wooded landscape that serves as a picturesque backdrop. The dynamism of the scene lies not in the action itself, but in the naturalistic and mimetic investigation of the characters, who are presented in the foreground.
In addition to the members of the Holy Family, the artist introduces non-canonical accessory figures, such as a young man-at-arms and a mother with her small child. These inclusions contribute to the de-sacralization of the episode, placing it within a dimension of human daily life and confirming the stylistic links to contemporary Florentine mural paintings, which also sought to explore a rustic and popular tone devoid of idealization.


Figure 2: The mural altarpiece of the chapel.

This attention to nature extends to the side walls, where two landscapes are set within elaborate painted frames and interspersed with monochrome panels featuring grotesques. These works, depicting woodland views with dwellings and *spacious evening skies*, establish themselves fully within the landscape genre and reinforce the naturalistic sensitivity that pervades the entire cycle.


Figure 3: The frescoed vaulted ceiling of the chapel.

In contrast to the naturalism of the mural altarpiece, the decoration of the small barrel vault follows a more traditional arrangement, reflecting the vestiges of Late Mannerism. The

2 The relocation operations lasted until 1788.
3 The chapel can be visited only upon official request to the designated offices of the Academy of Fine Arts of Florence.

vault is elegantly subdivided by fresco ornaments simulating figurative stucco reliefs and grotesque decorations, predominantly in white and gold (Fig. 3).
Below are some of the key elements of the work.
The Glory of Putti (at the center): Foreshortened from below upwards, these putti evoke sixteenth-century prototypes from the Correggesque circle, utilizing illusionism to expand the perceived space.
The Narrative Scenes (on the sides): The Marriage of the Virgin and the Visitation.
Archangels and Virtues: Among the allegorical figures, Mansuetudine (Gentleness) stands out for her originality and executive quality; depicted in an intimate and recollected manner, her meditative pose seems to be derived directly from classical statuary models (Barbolani di Montauto, 2005).

3. The importance of digitalizing this Site

This is an original work, one of the oldest yet least-known among those preserved at the Academy. For this reason, it was decided to digitalize the site and develop a digital visualization system for both the architectural environment and the frescoes it contains. To this end, the chosen modes of fruition are the walking simulator and VR – a choice that is arguably consistent with the original design of the Chapel: an enclosed, almost entirely frescoed space that possesses immersion as one of its native characteristics.
The significance of this work demands a continuation of the enhancement process that began with opening the site to the hall where it is housed, following the removal of the curtains that once covered it (Fig. 4). Within this framework, the developed application becomes a key tool to support the promotion and communication of this fresco cycle.

Figure 4: The Chapel of Giovanni da San Giovanni at the Academy of Fine Arts in Florence.

Specifically, the objectives set for the digitalization of the Chapel are significant across several levels.
Documentation and Preservation: To document the work for the first time through three-dimensional digital reconstruction for archiving purposes and to safeguard the paintings. In this specific case, it should be noted that there are no evident conservation issues. Consequently, the digitization process functions as an act of preventive safeguarding, laying the groundwork for the development of a Digital Twin. This digital replica is designed to integrate IoT sensors and BIM (or the Heritage Building Information Modeling) to monitor and ensure the structural and artistic integrity of the cultural asset over time: for example, the integration of real-time environmental data within the HBIM environment allows for the simulation of microclimatic impacts on the frescoed surfaces.
Accessibility: to make accessible a space that, despite recent improvements, remains largely unknown to most people both within and outside the Academy.
Scientific Research: high-end scientific digitalization allows not only for the viewing of the heritage site but also for remote study by specialists, thanks to high-resolution textures and the inclusion of technical documentation, such as reflectographies of the frescoes.
Education and Experimentation: to provide students of the Academy and other institutions with a study tool and an environment for artistic experimentation and dialogue.

4. Digitization and optimization

Regarding the digitalization of the work, the photogrammetric technique was selected for two primary reasons: the high fidelity of the textures and the replicability of the process.
While the Chapel of Giovanni da San Giovanni is an architectural structure, the most critical data for both conservation and communication remains the superficial layer of the plaster: the fresco. The chromatic fidelity, extraordinary in its vibrancy even centuries after its creation, becomes a fundamental tool for the Virtual Reality experience, catering to both expert scholars and a general audience.
Secondly, one of the core principles established within the AMABAFi project is the technical reproducibility of the acquisition processes using equipment available within the Academy. This hardware is easily accessible to undergraduate and doctoral students, who are expected to be increasingly involved in these workflows.
For these reasons, a methodology based on photogrammetry was defined. This approach does not preclude the future integration of the resulting datasets – enriched with metadata and paradata – with data derived from laser scanning or other emerging technologies.
For the photogrammetric acquisition was employed a 61-megapixel full-frame Sony ILCE-7RM4A camera, capturing data in RAW format. The final image resolution is 6376 × 9568 pixels.
To ensure uniform and controlled lighting throughout the acquisition phase, as well as to guarantee maximum color fidelity for the textures, a ring flash was used mounted directly on the camera lens.
Incident light was measured and color temperature verified using a Minolta Color Meter II to ensure chromatic consistency across all acquired images.
The entire photographic campaign was conducted handheld, without the use of a tripod. To ensure accurate photogrammetric reconstruction and support image alignment, 14 12-bit coded markers were positioned according to a specific layout.
The following acquisition parameters were kept constant throughout the session.
The field activity was conducted over a two-day period: the first day was dedicated to the primary photogrammetric survey, while the second, following a preliminary data quality assessment, focused on refining specific camera positions and increasing the overall data density.
The photographic acquisition was structured to ensure adequate image overlap and complete coverage of all surfaces (Fig. 5).

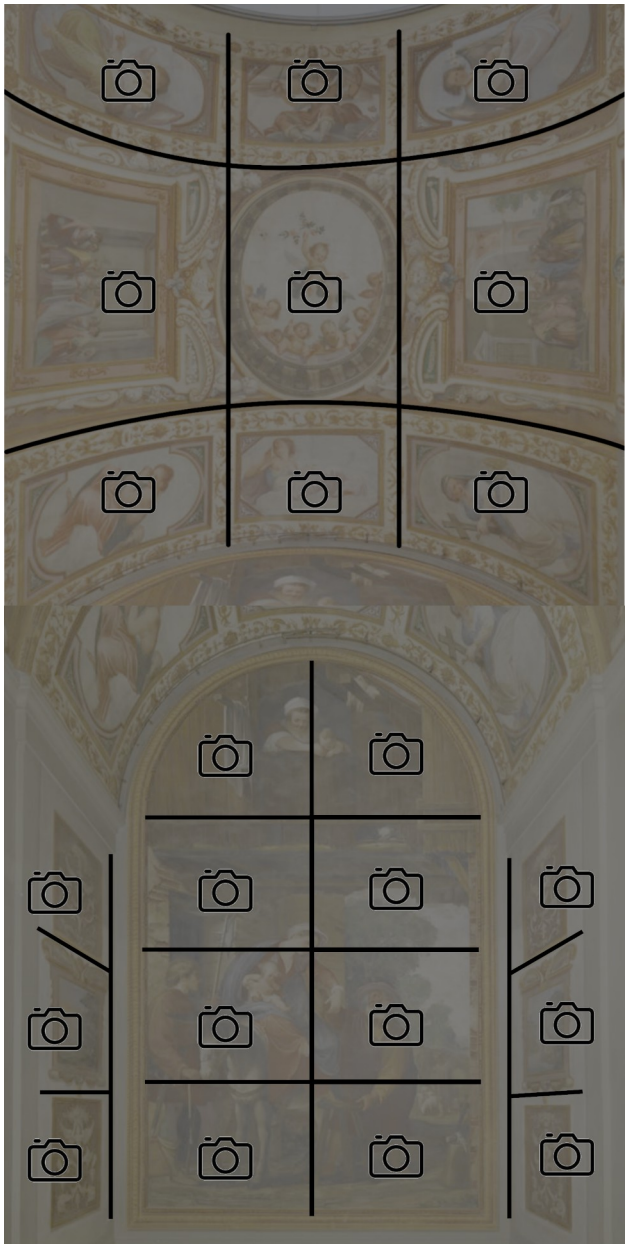

Figure 5: Photogrammetry scheme.

The frontal altarpiece: General images included 4 vertical wide-angle shots, plus 2 series of tilted images (right and left), each consisting of 4 vertical shots. It was ideally subdivided into eight quadrants, each acquired following a standardized shooting pattern designed to ensure adequate angular coverage. Specifically, nine images were captured for each quadrant, distributed as follows: one frontal image, orthogonal to the surface; two images with vertical tilt (one from above and one from below), at an angle of approximately ±20° relative to the surface normal; three images with right lateral tilt: one tilted 15° relative to the horizontal axis, and two additional images with a vertical tilt of approximately ±20°; three images with left lateral tilt: one tilted 15° relative to the horizontal axis, and two additional images with a vertical tilt of approximately ±20° (Fig. 6).
The side surfaces: Subdivided into 3 quadrants for each side. For each quadrant, 9 images were captured following the same pattern used for the front altarpiece.
The vault: Subdivided into 9 quadrants according to the painting's geometry. For each quadrant, 9 images were captured following the same standardized pattern.
The subsequent processing phase to generate the 3D model required approximately seven hours.

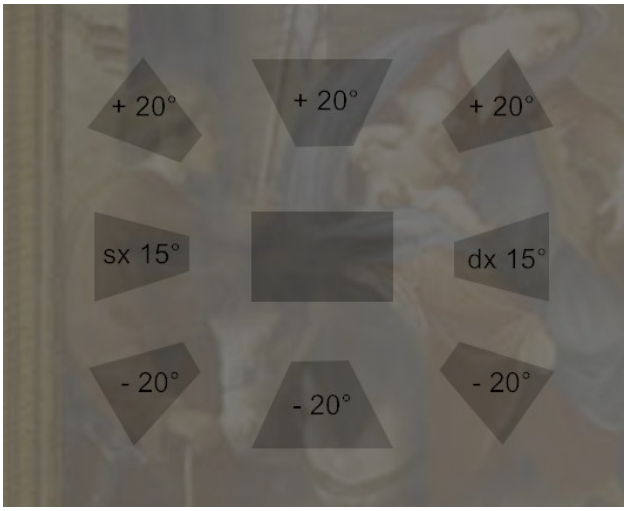

Figure 6: The orientations of the photographies taken during the photogrammetry process.

The photogrammetric processing was performed on an MSI Katana 15 computer, equipped with an Intel Core i7-12650H CPU, 16 GB of DDR5 RAM at 4,800 MHz, an NVIDIA GeForce RTX 4060 GPU with 8 GB of VRAM, and a 1 TB PCIe 4.0 SSD, operating in a Windows 11 Home environment.
Following the initial image alignment and the generation of the sparse point cloud, control points corresponding to the coded markers placed within the architecture were identified. The model was subsequently scaled by inputting measured real-world distances between the markers, ensuring dimensional consistency between the digital model and the physical object.
In terms of overall metric precision, following the scaling based on control points, the estimated error is approximately ±1 mm. This value is derived from the tolerance in the definition of the control points and the analysis of the residual error, which ranged between 0.0 mm and 0.1 mm.
The final 3D model was generated with a density of 12 milion of polygons. The texturing phase was conducted by setting a maximum texture resolution of 16k × 16k (maximal texture count), producing a total of 5 high-resolution textures, optimized to ensure a high level of visual detail and accurate chromatic reproduction of the surfaces.
The photogrammetric elaboration was carried out using RealityCapture 1.5.1. This choice follows the principles of availability and reproducibility of the AMABAFi project, as previously mentioned.
The resulting 3D object was archived as a primary model for preservation and potential future study; subsequently, an optimized derivative model was created for real-time rendering in Blender 4.4.
Initially, a 99.9% polygon reduction was performed on the original 3D model. The architectural structure of the Chapel was reconstructed from CAD plans as a mesh composed of planar surfaces, onto which the RGB data was subsequently re-projected. This allowed the textures to carry more weight in the model's performance budget, resulting in one texture with optimized UV (texture atlasing) space and a resolution of 4096 × 4096 pixels: this approach was implemented to reduce the draw calls to a single unit, given that the confined space of the

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Chapel would have made it impossible to prevent multiple separate textures from being visible simultaneously.
The chosen format for the albedo texture is the PNG, in order to have a better compression rate to avoid lag or glitch; also the PNG is a good compromise for the high fidelity of the superficial color. For the normal map is used the PNG, to avoid artefact during the real-time rendering.

5. VR Application and User Experience

The software architecture was built using Unity 2022.3.62f3 LTS (Long Term Support). This specific engine version was selected to prioritize computational efficiency and robustness in multi-platform deployment. The decision-making process was guided by two strategic requirements: first, the need for a streamlined runtime performance capable of sustaining high frame rates on standalone hardware; and second, the interoperability required to export assets across various modules of the broader multimedia archive (Amoruso & Buratti, 2022).
Furthermore, adopting this environment maintains methodological and technical continuity with the Academy's previous virtual heritage initiatives, most notably the digital twin developed for the exhibition *Il Culto del Bello. Antonio Canova, Giovanni degli Alessandri e l'Accademia di Belle Arti di Firenze* (Bellesi, 2022), thereby establishing a standardized pipeline for the AMABAFi project.
To ensure a seamless user experience, the 3D assets were integrated using the GLB. This format is widely recognized as the industry standard for efficient transmission and loading of 3D scenes, particularly in mobile and web-based VR. The entire environment was optimized to a total budget of approximately 50,000 polygons.
This deliberate reduction in geometric complexity, coupled with the implementation of a single-material architecture, drastically minimizes the CPU-to-GPU overhead. By reducing the number of Draw Calls to a minimum, the system prevents performance bottlenecks typical of high-fidelity architectural surveys in VR.
The visual fidelity of the frescoes is preserved through a specific texturing workflow. High-resolution PNG source files for both Albedo and Normal maps were synthesized into Atlas Maps to further consolidate draw calls. These textures were compressed using the ASTC (Adaptive Scalable Texture Compression) 4×4 profile. Unlike traditional compression formats, ASTC allows for fine-grained control over the bitrate-to-quality ratio, providing superior chromatic accuracy and surface detail while significantly reducing the VRAM footprint on the Meta Quest's mobile chipset. This same compression standard was extended to the Graphical User Interface icons to ensure visual coherence and rapid UI responsiveness.
The virtual environment is composed of 17 complex 3D entities, categorized to reflect the chapel's iconographic and architectural hierarchy.
The architectural shell: the primary structural mesh, integrating the floor and the counter-facade wall.
The central narrative group: high-resolution models of *the Rest on the Flight into Egypt*, featuring Mary, the Infant Jesus, and Saint Joseph.
The secondary figurative elements: the auxiliary figures of the soldier and the mother with child.
The vault assembly: a complex arrangement including the central *Glory of Putti*, the historiated scenes of *the Marriage of the Virgin* and the *Visitation*, and the series of *Archangels* and *Virtues*.
The landscape panoramas: the two lateral vistas flanking the altarpiece.
To facilitate a meaningful interaction with the artistic content, these elements were semantically segmented from the primary architectural surfaces. This was achieved through the creation of proxy meshes extracted with a minimal offset from the walls and vault. This layered geometry enables precise raycast-based selection.
While the figures in the main narrative scenes were manually contoured following their anatomical silhouettes for surgical interactive precision, the vaulted elements and landscapes were encapsulated within their original geometric frames (circular or rectangular), respecting the spatial syntax of the 17th-century decorative project.

Figure 7: VR interface, with highlighted figure.

The deployment of the final application as a fully immersive VR experience facilitates a high-fidelity engagement with the digital twin, characterized by a first-person, egocentric perspective. This spatial configuration allows for an intuitive exploration of the architectural volume, maintaining a direct 1:1 scale relationship between the user and the digital environment.
Navigation within the space is governed by a hybrid locomotion system.
Translation: positional movement is mapped to the primary analog joystick of the left controller, enabling smooth continuous locomotion. This allows the user to traverse the Chapel's floor plan while maintaining a stable vertical axis.
Orientation: The viewing direction is determined by the Three Degrees of Freedom (3DoF) head-tracking data provided by the headset's internal gyroscopic and inertial sensors. This ensures a strict proprioceptive alignment between the user's physical head movements and the virtual camera's rotation, a fundamental requirement for minimizing vestibular-ocular conflict and mitigating the risk of cybersickness.
The interactive framework utilizes a raycast-based pointer system that originates from the user's handheld controllers.
Interactive entities, including both 3D scene objects (semantically segmented frescoes) and 2D Graphical User Interface elements, are targeted via the raycast. The primary trigger on the controller acts as the universal confirmation input.
To streamline the UX, a unified input mapping was adopted. The trigger serves as the singular interaction point for diverse tasks: engaging with 3D hotspots, confirming menu selections, and managing the scrolling mechanics for extended textual descriptions and archival imagery.
When the raycast intersects a valid target, the system provides immediate visual feedback, highlighting, confirming the object's interactable status before the user executes the selection.
The user interface (Fig. 7) follows a minimalist design to ensure that elements are as unobtrusive as possible. An icon at the bottom right indicates the user's orientation: the arrowhead points to the forward direction, similar to north on a compass; in the top left, a *hamburger* menu icon (consisting of three horizontal lines) provides access to different visualization modes, charging different scenes.

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The core scene features the Chapel in full color with interactive, selectable figures. By accessing the menu, users can explore various sections: a historical-artistic introduction accompanied by text and images (Fig. 8); a 3D view of the Chapel in grayscale (black and white); and a dedicated 3D scene where the paintings are isolated and unfolded to allow the consultation of the infrared reflectography (IRR) data previously acquired by Prof. Juri Ciani (Fig. 9).
In the colored scene selecting individual objects, such as figures, architectural elements, or significant details, provides access to their descriptive metadata.


Figure 8: Detail of the Chapel vault fresco: *the Visitation*.

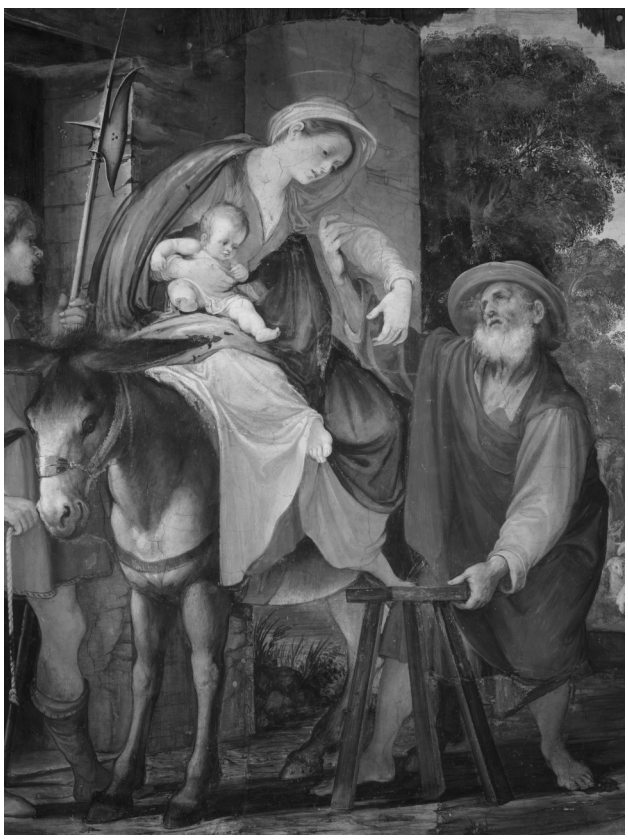
Figure 9: Reflectography of the central fresco by Professor J. Ciani.

The system triggers the display of a contextual information panel when the user confirms a selection – via the controller's primary trigger – on a figure previously identified by the raycast-based highlighting system.
As seen in similar precedents, virtual reality facilitates a deeper analysis of the visual model (Vallet, 2012), distinguished in this case by the freedom of movement and the specificities of the study at hand.
Currently, the application operates as a standalone offline system, with all 3D models and high-resolution textures stored locally to ensure maximum performance and stability.
However, a cloud-based streaming architecture for assets is presently under development. While the domestic adoption of high-end VR devices remains relatively limited, this implementation aims to future-proof the project for broader accessibility.
Concurrently, a version of the application optimized for WebXR will be hosted on the AMABAFi online platform. This ensures a cross-platform experience, allowing users to access the digital heritage of the Chapel via standard web browsers, thus bridging the gap between specialized VR hardware and general public accessibility.

6. Conclusion

The present research is situated within a broader strategic framework dedicated to the digitalization and valorization of the artistic heritage held by the Academy of Fine Arts in Florence. In this context, it is imperative for cultural institutions to evolve beyond traditional digital archiving toward the development of advanced ecosystems for the dissemination and semantic interrogation of 3D datasets. The integration of such tools aligns with the principles of the London Charter, ensuring that computer-based visualizations are not merely aesthetic products but intellectually rigorous research outputs.
Future development trajectories include the integration of spatialized audio guides – essential for enhancing the sense of presence in virtual reality – and the systematic expansion of the 3D repertoire. This entails the transition from surface-only photogrammetry to the full volumetric reconstruction of the central *Rest on the Flight into Egypt* scene and the ancillary decorative elements, such as bas-reliefs.
Current challenges primarily concern the user experience for non-expert audiences. To transition from a purely qualitative assessment to a quantitative analysis of the application's impact, the research group has scheduled a series of public testing sessions.
A critical point of discussion within the Digital Heritage community is the risk of digital substitution – the concern that a virtual experience might replace the physical visit. However, in the case of the Chapel of Giovanni da San Giovanni, the digital twin serves as an essential tool for preventive conservation and remote accessibility. Given the current bureaucratic and structural constraints that render the site inaccessible, the VR application acts as a surrogate experience that promotes the valorization of the work, also without risking the integrity of the physical frescoes.
From an art-historical perspective, the Academy's heritage has been extensively studied by specialists. The recent introduction of Research Doctorates within the AFAM (Alta Formazione Artistica e Musicale) system, coupled with funding from the PNRR EAR (Enacting Artistic Research) project – Work package 4, has catalyzed a transdisciplinary synergy. This environment fosters collaboration between art historians, restorers, and developers, ensuring that the digital workflow remains anchored in philological accuracy.
This renewed interest, characterized by a robust cross-disciplinary collaboration, represents both a primary objective and one of the most significant achievements of the current

project. Such a transdisciplinary synergy is essential for the evolution of the AFAM research framework. By overcome traditional academic silos, this collaborative model ensures that the digitalization process is not merely a technical exercise but a philologically grounded methodology, capable of generating new interpretive layers for cultural heritage
The selection of standalone VR headsets as the primary delivery medium is a strategic cornerstone of this research. By eliminating the physical tether to a computer, the technology allows for a fluid, unencumbered navigation of the space.
This approach remains remarkably faithful to the original 17th-century artistic intent: the Chapel was designed as an intimate and immersive environment.

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Sara Onofrietti (PhD Student): Art-Historical contextualization and critical analysis.

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