A comparative evaluation of 3D reconstruction with photogrammetry, NeRFs and 3D Gaussian Splatting in Cultura Heritage Restoration

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Abstract

In the domain of Cultural Heritage Restoration, the demand for high-fidelity 3D models with accurate textures and geometry is critical for documentation, analysis, and conservation. While photogrammetry remains the standard in restoration field due to its ability to produce reliable, high-resolution textures, it faces limitations when dealing with reflective, transparent, or textureless surfaces. Recent advancements in in neural rendering techniques, particularly Neural Radiance Fields (NeRFs) and 3D Gaussian Splatting, offer promising alternatives by enabling photorealistic scene reconstruction from unstructured image sets. This study presents a comparative evaluation of photogrammetry, NeRFs, and Gaussian Splatting, assessing their performance and suitability for restoration-oriented applications, with particular attention to scenarios where the limitations of photogrammetry hinder comprehensive documentation. The evaluation is conducted on a set of heterogeneous case studies, ranging from sculptures and design objects to architectural heritage buildings.

1. Introduction

The restoration of Cultural Heritage (CH) involves direct interventions on artworks to improve their conservation state and ensure their preservation for future generations. Every restoration process transforms the artwork from an initial to a final condition and becomes part of its story. Since every intervention alters the material and sometimes removes historical layers, accurate documentation is essential. Such documentation should include information about materials, execution techniques, historical background, current alterations, diagnostic and archaeometric analyses. Public sharing of such data is considered a professional and ethical responsibility aimed at promoting collaboration and knowledge exchange among those involved in conservation.

In the current practice, all restorers are required to document the performed operations in detail, the status of the artwork before and after the interventions, and to provide the results of their analysis. This sector is moving towards a complete digitization of information and the use of increasingly innovative investigation techniques such as diagnostic tools, multi-spectral image analysis, and 3D scanning.

National heritage agencies play a key role in regulating and evaluating restoration interventions. These institutions require increasingly accurate digital documentation to assess the impact of conservation work and to guarantee respect for the historical and artistic significance of cultural artifacts (Carmeliti and Catalano, 2025; Catalano et al., 2020).

Within this digital transition, the production of 3D models has become an ordinary practice. Restorers demand models characterized by extremely high-resolution textures and strong visual clarity, as these are expected to reveal minute surface details useful for interpreting the conservation state of artworks. Furthermore, these models must allow the export of detailed orthophotos, which are fundamental for graphic documentation, condition mapping, and ensuring compliance with conservation ethics.

Today photogrammetry represents the restoration benchmark for generating textured models with high metric accuracy. This technique is employed at various stages of CH documentation, from small artefacts to ancient buildings, and supports the production of point clouds, textured 3D meshes, and orthophotos. Quantitative measurements are possible directly on the 3D model, allowing the acquisition of dependable metric data for conservation assessment and intervention planning.

However, photogrammetry often involves labour-intensive workflows and is highly sensitive to acquisition conditions. Furthermore, photogrammetry performs poorly with reflective, transparent, or featureless surfaces that may not be captured properly in photographs, such as building windows, metal elements, gold leaf decorations, or certain design objects. Furthermore, these methods are unable to fully recover unreconstructed regions or "over-reconstruced," sometimes creating non-existent geometries (Nicolae et al., 2014).

Recent advances in neural scene representation have transformed how 3D geometry and appearance can be inferred from images, achieving photorealistic reconstructions.

The Neural Radiance Fields (NeRF) technique, for example, models a scene as a continuous volumetric function based on an initial set of sparse views. This is learned by a multi-layer perceptron (MLP), that maps spatial coordinates and viewing directions to colour and density values (Mildenhall et al., 2021, Tancik et al., 2023). MLPs are trained to generate 3D objects from two-dimensional images. They take a 5D-vector function input, comprising spatial coordinates within the scene (x, y, z) and two angles (azimuthal and polar) that define the viewing direction (ϑ, φ). It outputs a volume density, denoted as σ, and an RGB colour, dependent on the viewing direction (Mildenhall et al., 2021, Croce et al., 2023).

3D Gaussian Splatting (3DGS), otherwise, is a real-time alternative that models scenes using sparse sets of gaussian primitives. This method enables efficient rendering at high frame

rates, offering improved performance in terms of material appearance, depth perception, and brightness handling (Kerbl et al., 2023; Clini et al., 2025).
The method uses a set of 3D gaussian primitives initialized from sparse camera calibration points to represent a scene, providing a continuous volumetric representation while avoiding unnecessary computation in empty space. Through an interleaved optimization process, the parameters of the gaussians, including the anisotropic covariance, are progressively refined in order to accurately model the geometry and appearance of the scene. A fast, visibility-aware rendering strategy enables efficient training and real-time visualization, achieving high visual quality across different datasets (Kerbl et al., 2023).
Both approaches rely on unstructured image collections, sharing the same data requirements as photogrammetry but differing radically in representation, performance, and visual fidelity. Moreover, the tested NeRFs systems allow you to export point clouds and textured meshes in .ply and .obj formats. From 3DGS, you can export point clouds in a specific .ply format. It is important to note that, in the context of restoration practice, particularly when assessing the conservation state of artworks, the availability of an accurate mesh is not always a primary requirement. In many diagnostic and documentation activities, the interpretability of surface appearance, material characteristics and visual continuity is more important than mesh quality.
Hence, the applicability of these approaches to restoration-oriented documentation, where interpretability, color fidelity, and texture resolution are crucial, could represent a significant advancement in digital tools for the restoration field, particularly if they prove capable of overcoming the aforementioned intrinsic limitations of photogrammetry.
This study evaluates the performance of each method when dealing with surfaces and geometries that challenge traditional photogrammetry pipelines, focusing on reconstruction fidelity, completeness, surface detail, and visual realism. The analysis explores their complementary roles in restoration oriented documentation through heterogeneous case studies, including sculptures, design objects, and architectural heritage.

2. State of the art

Three-dimensional documentation of CH is currently dominated by *Structure from Motion* (SfM) techniques. These methodologies are considered the standard thanks to their ability to produce metrically accurate digital replicas using low-cost photographic equipment. However, traditional photogrammetry has inherent limitations when applied to objects with complex optical properties: reflective, transparent, or textureless surfaces compromise feature matching, often leading to noisy, incomplete, or geometrically distorted models (Nicolae et al., 2014, Mazzacca et al, 2023).

To overcome these obstacles, recent research has focused on Neural Radiance Fields (NeRF), first introduced in 2020 (Mildenhall et al., 2021). The main advantage of these technologies is their view-dependent nature, which enables them to accurately model lighting and specular reflection variations that photogrammetry tends to “flatten” (Croce, et al., 2024). Despite their impressive visual realism, NeRFs face challenges such as long training times, sensitivity to the accuracy of photographic poses, and a tendency to generate noisy point clouds or artefacts known as “floaters” (Murtiyoso and Grussenmeyer, 2023; Basso et al., 2024).

A breakthrough came with the introduction of 3D Gaussian Splatting. Unlike NeRF, 3DGS uses a set of explicit anisotropic gaussian primitives to represent the scene. Combining the advantages of volumetric representations with the efficiency of rasterization, this technique enables real-time rendering and reduces optimisation times compared to NeRF (Kerbl et al., 2023; Ye et al., 2024).
Recent studies have begun to systematically compare these technologies with SfM workflows for specific cases involving CH.
It has been observed that, in conditions of reduced data or low resolution and reflective artifacts, these new systems offer greater model completeness and material fidelity than photogrammetry, although the latter remains superior in terms of pure metric accuracy on opaque and well-structured surfaces (Croce et al., 2024; Clini et al., 2025).

In the field of conservation and restoration of CH, the application of NeRFs and 3DGS for virtual reconstruction, digital preservation, and conservation purposes remains relatively underexplored, with only a few publications explicitly addressing these methods. Current literature highlights how these systems can overcome the key challenges of traditional photogrammetry (Lee et al., 2025; Vasiljević et al., 2025; Croce et al., 2023). However, most documented applications tend to focus on synthesizing new views for immersive visualization, creating virtual exhibitions, and documenting inaccessible archaeological sites (Vasiljević et al., 2025; Condorelli et al., 2021; Palestini et al., 2022).
To date, there has been a lack of studies analysing these methodologies from the perspective of restorers' technical and scientific needs during the practical phases of conservation.
Therefore, it is essential to investigate whether NeRF and 3DGS can truly meet the strict professional requirements of restoration by evolving from simple visual aids into certified scientific measurement and analysis tools with accurate geometric accuracy and material rendering.
This study investigates whether these neural methods can offer practical advantages over traditional photogrammetric workflows when applied to restoration oriented 3D modelling tasks. Several datasets were processed using multiple open-source implementations of NeRF, as Instant NGP (Müller et al., 2022) and Nerfstudio (Tancik et al., 2023), and 3DGS, as gaussian-splatting (Kerbl et al., 2023), gsplat (Ye et al.,2025), and PostShot v1.0.110 (Jawset Visual Computing, 2025), and compared against photogrammetric reconstructions generated with RealityScan 2.0. (Epic Games, 2025).

3. Case studies and methodology

3.1 Case studies

The case studies were selected to represent a diverse range of scenarios commonly encountered in CH documentation, paying particular attention to conditions that challenge traditional photogrammetric workflows. The three case studies all exhibit material, optical or geometric characteristics that usually restrict the effectiveness of photogrammetry, making them an ideal testbed for evaluating alternative approaches.
Specifically, the case studies include (Table 1):

1. A gypsum sculpture of *Venus*, characterized by a smooth, homogeneous, and largely monochromatic surface. Such material properties significantly reduce the presence of distinctive visual features, which are essential for robust keypoint detection and image matching within SfM. This scenario is representative of a common issue in heritage documentation, where uniform surfaces often lead to incomplete or unstable reconstructions (Nicolae et al., 2014).

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In addition, the acquisition environment presented difficult lighting conditions due to strong natural light coming in through the windows and suboptimal artificial lighting.

2. *Tavolo Erba*, a design object by Franco Mello. In this case, the transparent supporting element introduces additional challenges. Transparent materials produce inconsistent correspondences and reconstruction artefacts, making this case particularly suitable for assessing the robustness of neural rendering techniques when dealing with optically complex surfaces.
3. The courtyard of *Vecchia Dogana* building in Verona. Built in the 18th century, this complex is centered around a large, rectangular courtyard surrounded by a recursive colonnade, and a giant Doric colonnade runs along the side opposite the entrance. The structure is interspersed with numerous openings (windows and glass doors), and particularly enormous windows that correspond to the gigantic colonnade.

The case-study objects were documented using a digital camera equipped with a full-frame sensor and by a DJI Mini 2 drone for the building. A series of images were taken from various viewpoints, with sufficient overlap between successive shots.
For each artifact, more than 100 images were acquired in RAW format to preserve the full radiometric information specifically, 254 for the Venus, 212 for the design table, and 522 for the building. Subsequently, the images have been preprocessed using Adobe Lightroom to apply standardized corrections for white balance, sharpness, and contrast. Image resolution was uniformly reduced to 1250 x 780 pixels, taking in account the resolution limits of some neural rendering approaches (Kerbl et al., 2023) and the computational capabilities of the workstation used for the experiments.

Case studies	Images	Characteristics
Venus	254	- Smooth, homogeneous surface. - Challenging lighting conditions.
Tavolo Erba	212	- Texturless surface. - Transparent support. - Cross-polarized acquisition.
Vecchia Dogana	522	- Reflective windows. - Repetitive volumes. - Poor lighting conditions.

Table 1. Presentation of the case studies

3.2 Tested software

To enable a comparison between traditional photogrammetry and recent neural rendering approaches, a set of representative software solutions were selected and tested. The following section provides a brief description of the main characteristics of each application. This is intended to provide context for the experimental results discussed in subsequent sections.
RealityScan (formerly RealityCapture) is a photogrammetry software that can be used to create 3D models from unordered photographs or TLS point clouds.
Its features include image orientation, automatic calibration, polygon mesh calculation, colouring and texturing, parallel projections, georeferencing, digital surface modelling, coordinate system conversion, simplification, scaling, filtration, smoothing, measurement and inspection, as well as various export and import options. In addition, it is designed to be hardware efficient.

The Instant NGP framework developed by Müller et al. (2022) for NVIDIA Research, was used in this study as one of the reference implementations for NeRF reconstruction. The system enables fast training and real-time visualization of NeRF models from posed image dataset through multi-resolution hash encoding and a highly optimized CUDA architecture. The camera posture estimation is carried out using COLMAP to ensure compatibility with standard photogrammetric workflows. The framework is implemented in C++ and requires a NVIDIA GPU. Optional Python bindings and additional libraries can be used to support interactive workflows and accelerated mesh-based training. The graphical user interface can be launched by running a command in an Anaconda environment. The application provides a real-time web-based viewer and supports exporting data in multiple formats, including point clouds and meshes.
The other application used to test the NeRF reconstruction was Nerfstudio. Introduced by Tancik et al. (2023), Nerfstudio is a modular Python framework based on PyTorch, designed to consolidate innovations in NeRFs research into reusable plug-and-play components. This system requires NVIDIA graphics card with CUDA installed (specifically tested with version 11.8), and Python 3.8 or higher.
Nerfstudio integrates a real-time web viewer for interaction during training and supports various export modes, including point clouds and meshes. The framework supports formats from tools such as COLMAP or photogrammetry software such as Metashape and RealityCapture.

Proposed by Kerbl et al. (2023), gaussian-splatting introduces an explicit representation of the scene using anisotropic 3D gaussians, enabling real-time rendering, based on OpenGL, at 1080p with a frame rate of ≥30 fps. The system was developed in Python with the aid of custom CUDA kernels for rasterization and optimises gaussian parameters (position, covariance, opacity and spherical harmonics) starting from a sparse point cloud generated using SfM.
The system uses an optimisation cycle that alternates between updating the gaussian parameters and adaptive density control. This mechanism allows gaussians to be cloned in under-reconstructed areas or split in areas where a single gaussian covers too large an area, progressively improving structural detail.
The gsplat framework, proposed by Ye et al. (2023), provides a Python interface compatible with PyTorch and a CUDA-based back end optimized for efficient training and rendering. The framework is designed to reduce computational and memory requirements while preserving visual quality comparable to the reference implementation.
The rendering process is fully differentiable, enabling joint optimization of gaussian parameters and camera poses, while additional features such as advanced densification strategies, anti-aliasing, and depth rendering support improved stability and downstream surface reconstruction.
In addition, Jawset Postshot is a production-oriented software application designed to generate 3D reconstructions from photographs or videos using radiance field techniques. It provides an end-to-end workflow for importing images, configuring and training radiance field models. All processing is performed locally, ensuring user control over data and workflows. A NVIDIA GPU is necessary to run this software.

Tests were run on a machine with an Intel(R) Core(TM) i9-14900HX (2.20 GHz) processor (CPU), 16,0 GB (15,6 GB usable) of RAM, and the NVIDIA GeForce RTX 4070 Laptop GPU as Graphic Card.

4. Results and discussion

The evaluation focuses on a comparative analysis between traditional photogrammetric reconstruction and neural rendering approaches to assess their suitability for CH documentation and restoration workflows. The analysis aims to investigate whether neural-based methods can complement or enhance established photogrammetric techniques, particularly in challenging scenarios commonly encountered in heritage digitization.
Reconstruction results obtained using photogrammetry, NeRFs, and 3DGS were compared highlighting notable differences in geometric accuracy, surface completeness, and visual fidelity among the tested approaches. Attention was paid to the ability of each method to preserve fine surface details and to provide visually interpretable representations suitable for restoration analysis.
Processing times were evaluated for each dataset by considering the complete reconstruction pipelines. The photogrammetric workflow includes image orientation, dense point cloud generation, and textured mesh reconstruction, while the NeRF and 3DGS workflows comprise image orientation, model training, interactive visualization through web-based viewers, and the export of point clouds and surface meshes. This comparison provides insights into the computational demands and practical feasibility of each approach in real-world restoration scenarios (Figure 1).

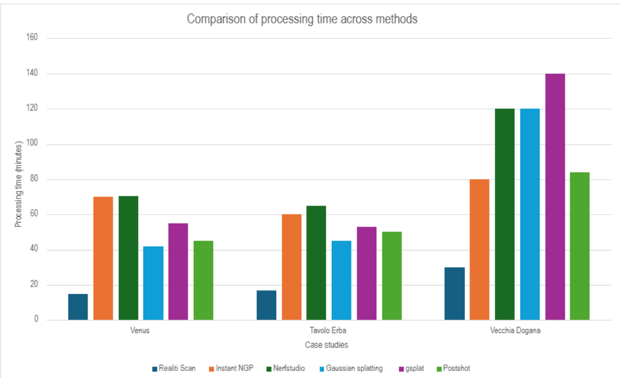

Figure 1. Processing time for the three case studies.

4.1 Venus sculpture

This gypsum sculpture is characterized by a smooth, homogeneous, and largely monochromatic surface. The object was exhibited in a location close to large windows, resulting in strong natural illumination and pronounced lighting contrasts that were difficult to fully control during image acquisition. Additionally, the artificial lighting conditions were suboptimal.
The photogrammetric reconstruction performed with RealityScan consistently outperformed all the tested neural rendering approaches, both in terms of processing time and visual quality. The photogrammetric workflow proved to be more efficient overall, requiring shorter computation times to produce a complete, metrically coherent, and visually detailed 3D model. From a qualitative perspective, RealityScan delivered the most accurate and stable texture reproduction, preserving the minimal surface variations (small lacunae, scratchs, abrasion), tonal gradients, and the typical manufacturing marks of gypsum artifact obtained through moulding technique. These details are crucial for restoration oriented analysis, as they directly support the assessment of surface condition and material decay.
As the figure 2 shows that NeRF-based reconstructions (Instant-NGP and Nerfstudio) and 3DGS approaches exhibit softer and less consistent textures, with localized noise, loss of fine surface detail, and residual artefacts, particularly in areas with limited geometric or chromatic variation.

Figure 2. A visual comparison of the results obtained from the different approaches

Among the neural methods, gaussian-splatting and gsplat achieved more stable visual results than NeRFs in terms of overall shape continuity; however, they still failed to reach the level of texture sharpness and surface readability obtained through photogrammetry. Even though with better performance, Postshot had similar limitations. These included a smoother appearance and reduced local contrast, which further affected the interpretability of surface features relevant to conservative analysis.

However, the visual comparison highlights a different behaviour when focusing on the description of volumetric continuity (Figure 3). In this context, neural rendering approaches provide a more coherent and visually continuous representation of volumes, particularly in areas characterized by the alternating solid and void regions. Neural systems reconstruct elements such as legs, supporting structures (metal frames), and the negative spaces between them more accurately than photogrammetry.

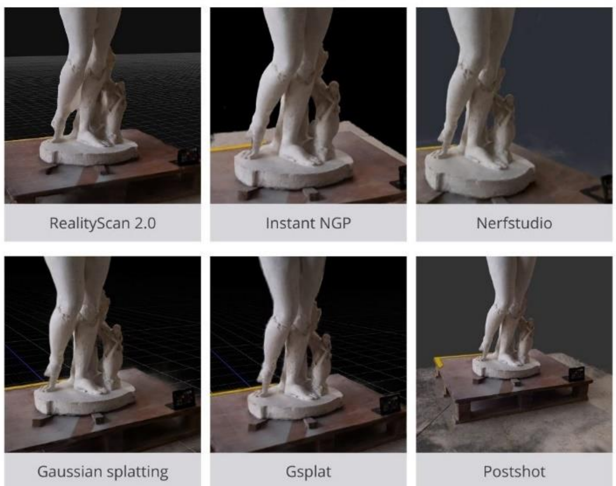

Figure 3. A comparison of the lower part of the sculpture across all the tested methods.

Although these volumetric improvements do not directly translate into visual detailed object suitable for the needs of restorers, they demonstrate the potential of neural representations to better interpolate missing geometry in complex spatial configurations. This behaviour is especially evident in 3DGS

methods, which show stable volumetric continuity even in regions where photogrammetric reconstruction exhibits gaps, irregularities or the creation of non-existent geometries.
In this case study, neural rendering techniques did not offer clear advantages over photogrammetry in terms of texture quality and surface detail, revealing intrinsic limitations. However, the analysis also highlights that neural approaches can provide a more coherent perception of volumetric continuity in geometrically complex areas.

4.2 Tavolo Erba

This design artwork by Franco Mello represents a particularly challenging case study due to the combination of a largely monochromatic and weakly textured surface, and the presence of a central supporting element made of transparent and reflective plastic. To mitigate reflections and specular highlights during image acquisition, the dataset was captured using cross-polarized photography.
Figures 4 and 5 show that traditional photogrammetry and RealityScan produced high-quality textures with sharp and accurate details on the opaque components of the object. However, the transparent central support could not be reconstructed, resulting in missing or collapsed geometry in this region. This outcome is consistent with the well-known limitations of photogrammetry, even under controlled acquisition conditions.
In contrast, 3DGS based approaches (gaussian-splatting, gsplat, and Postshot) were able to reconstruct the central transparent leg, providing a visually coherent volumetric representation of the entire object. Although the resulting texture quality appears less detailed compared to the photogrammetric model.
Additionally, gsplat experienced difficulties generating the lower part of the object, i.e., the area in contact with the base on which the artwork was placed.
NeRF based methods (Instant-NGP and Nerfstudio), on the other hand, failed to produce a meaningful reconstruction of the table. As shown in Figure 4, the resulting models exhibit severe instability, noise, and loss of structure. While a definitive explanation is beyond the scope of this study, this behaviour may be attributed to the use of cross-polarized imagery, which suppresses lighting cues that are essential for optimizing the radiance field. It may also be attributed to the visually homogeneous surrounding environment, which limits the availability of informative visual features.
Overall, this case study highlights that, while photogrammetry remains superior for reproducing textures with high fidelity, 3DGS approaches are particularly effective at handling transparent and reflective elements. Conversely, NeRF-based techniques appear sensitive to acquisition strategies and scene characteristics, which limits their applicability in this scenario.

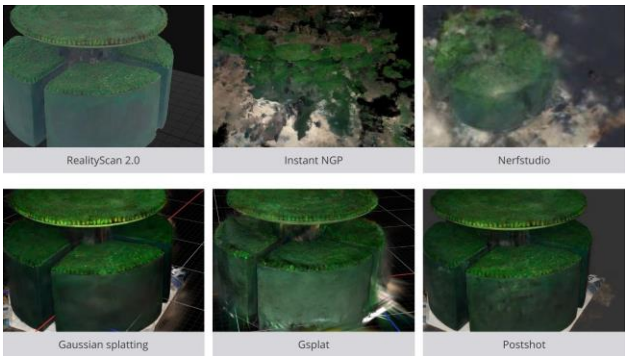

Figure 4. A visual comparison of the reconstruction obtained from the different approaches.

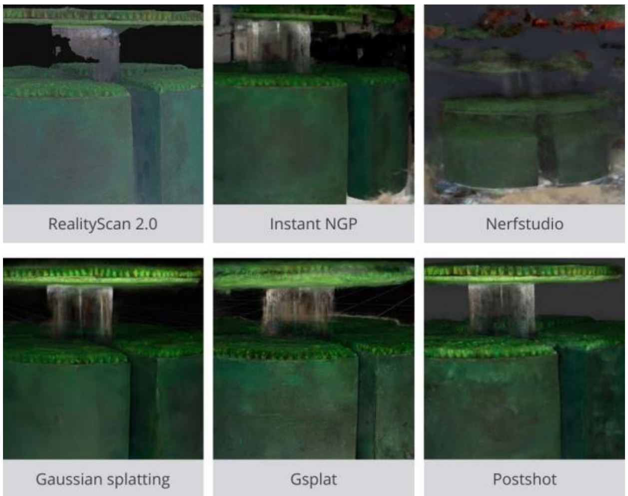

Figure 5. A comparison of the reconstruction of transparent central element.

Given the poor performance of NeRF-based systems, multiple training runs were performed with identical settings, but the results were consistently unsatisfactory. To investigate whether this behaviour was related to the image acquisition strategy, an additional dataset was captured using cross-polarized photography of the Venus sculpture discussed earlier. In this case, NeRF based methods successfully converged, producing a coherent representation of the sculpture. This comparison suggests that the failure observed for the Tavolo Erba is not attributable to cross-polarization alone, but rather to the visual homogeneity of the scene.

4.3 Vecchia Dogana

The third case study concerns the courtyard of the Vecchia Dogana building in Verona. This building is characterized by a strong architectural regularity, as well as the presence of complex elements such as windows, and thin metal balustrade. The results highlight significant differences between the various methods tested (Figures 6 and 7).
Although photogrammetry provided an accurate overall rendering of the wall surfaces with good colour quality and an accurate representation of the main volumes of the building, it showed clear limitations in the handling of transparent and reflective materials. The windows appear, in fact, incomplete or overly reconstructed (particularly in areas where natural light is reflected). The metal balustrade on the second floor was not reconstructed due to its thin and intricate details.
Conversely, neural rendering techniques such as gaussian-splatting, gsplat and Postshot are more effective at reproducing the spatial continuity and volumetric perception of these complex elements. While the texture definition is generally lower than that achieved through photogrammetry, these methods are much better at representing thin elements and glass surfaces, thereby maintaining greater visual consistency within the architectural ensemble.
The results of the tests on the NeRF systems show a clear difference between the two implementations considered. Nerfstudio provided a solid and visually convincing reconstruction: while the rendering of the metal balustrade does not match the completeness and continuity seen in 3DGS-based systems, the rendering of the roof was particularly accurate. This method effectively separated the architectural surfaces from the

bright sky in this case, avoiding interference and fusion artefacts between the edge of the roof and the background.
On the other hand, Instant NGP produced a less consistent result. Noisy point clouds that did not exist in the central area of the scene were added, compromising the overall legibility of the architectural space. The description of details is also less accurate and more inconsistent than with Nerfstudio, with a clear loss of definition in decorative parts and small elements. One possible explanation for these differences is that Instant NGP is more sensitive to the reflectance conditions of surrounding surfaces and strong variations in lighting.
In this case, neural rendering techniques are particularly interesting as complementary tools, especially when the aim is to produce a visually consistent rendering of complex or problematic elements for photogrammetry, such as thin structures, glass and reflective surfaces.

Figure 6. A visual comparison of the reconstruction obtained from the different approaches.

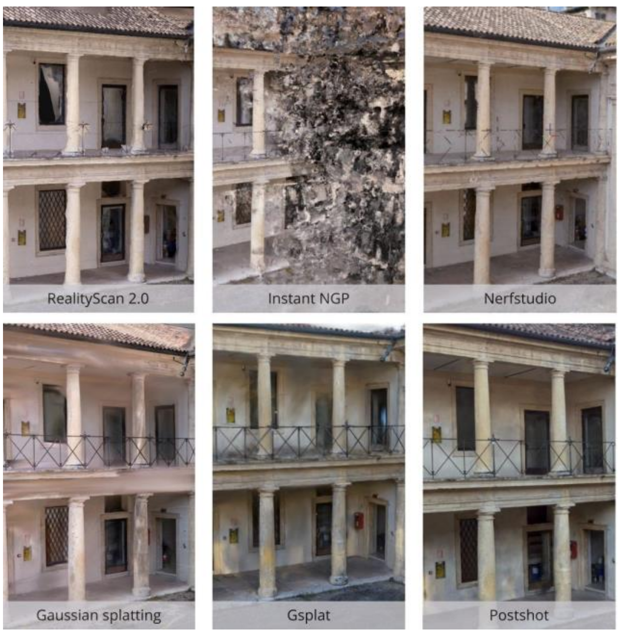

Figure 7. A comparison of the reconstruction of the windows and the thin elements.

4.4 Discussions

Overall, the results obtained from the three case studies confirm that photogrammetry remains the most robust and reliable solution for the restoration and documentation of artworks, both before and after restoration.
From the restorer's perspective, high-resolution textures and visually accurate models play an important role in supporting the analysis of conservation state, including the identification of colour alterations, surface degradation, and material characteristics, as well as the interpretation of execution traces when present. In these contexts, photogrammetry ensures superior texture quality and greater geometric reliability, providing an interpretation consistent with direct observation of the artwork.
Although techniques based on NeRF and 3DGS show considerable potential in terms of volumetric rendering and complex geometry management, they still have significant limitations in terms of restoration requirements.
In particular, the texture quality is generally poor, resulting in a loss of fine detail that compromises surface readability and makes diagnostic and material analysis more challenging. However, these approaches have proven more effective in handling elements critical to traditional photogrammetry, such as transparent or reflective surfaces, and areas characterized by thin elements or the alternation of solid and void regions. In our case studies, neural render systems, particularly 3DGS systems, provide a more continuous and perceptually convincing volumetric representation. However, they are less suitable for detailed surface analysis.
These results show that neural techniques cannot yet replace traditional photogrammetry in documentation contexts aimed at restoration but can rather be considered complementary tools.
Their use is particularly interesting for immersive visualization, perceptual rendering of volumes, and exploration of parts that are difficult to acquire with traditional image-based methods.
In conclusion, this study confirms that the choice of digitization technique should be guided not only by computational performance or technological innovation, but above all by the cognitive and operational objectives of restoration, for which texture quality and legibility remain essential requirements.

5. Conclusions

This study investigated and compared photogrammetry, Neural Radiance Fields, and 3D Gaussian Splatting for the digital reconstruction of CH artefacts and architectural elements, with a specific focus on the requirements of conservation and restoration practice. The experimental results confirm that photogrammetry remains the most reliable and mature technique when high-resolution texture fidelity, geometric accuracy, and surface interpretability are required. Photogrammetric models proved essential for the accurate assessment of material properties, surface alterations, and, where applicable, execution techniques.
NeRF-based methods showed promising capabilities in handling challenging lighting conditions and large-scale architectural scenes, producing visually coherent radiance fields with smooth illumination transitions. Among the tested systems, Nerfstudio delivered the most stable and visually consistent reconstructions. Nevertheless, NeRFs exhibited limitations in terms of texture sharpness, reflectance surface (see the result of Vecchia Dogana with Instant NGP) and computational efficiency, reducing their suitability for rigorous conservation-oriented analysis. Additionally, the issue regarding the Tavolo Erba, which was acquired using cross-polarized photographs, is still unresolved as the model has not been made available for use.
3DGS methods emerged as a compelling intermediate solution: its ability to reconstruct transparent and reflective elements represents a substantial advantage in terms of perceptual completeness and visual integrity, overcoming some intrinsic constraints of photogrammetry. However, limitations persist in

surface extraction and interoperability with established restoration workflows.
Overall, the results suggest that neural rendering techniques should not be regarded as replacements for photogrammetry, but rather as complementary tools whose strengths lie in visualization, interpretative support, and immersive applications. For conservation and restoration purposes, where geometric precision and high-quality textures remain essential, photogrammetry continues to represent the reference methodology.
For restorers, the integration of high-fidelity photogrammetric models with neural representations oriented toward volumetric completeness could be a promising future prospect, especially in complex scenarios or in the presence of problematic materials.
Future research should therefore focus on hybrid and integrated workflows, leveraging the respective strengths of photogrammetry, NeRFs, and 3DGS to support both analytical and communicative needs in CH documentation.

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