



XVII CONGRESO INTERNACIONAL
Expresión Gráfica Aplicada a la Edificación
APEGA CARTAGENA 2025
OCTUBRE
PENSAMIENTO GRÁFICO 02 | 03 | 04

How to cite: Perticarini, M; Condorelli, F.; Giordano, A.. THE SURVEY OF COMPLEX ENVIRONMENTS FOR IMMERSIVE REALITY PROJECTS USING GAUSSIAN SPLATTING: THE SALA TERRENA OF THE SCUOLA GRANDE DI SAN MARCO. Graphic thinking. Proceedings of XVII INTERNATIONAL CONFERENCE ON GRAPHIC EXPRESSION APPLIED TO BUILDING – APEGA CARTAGENA 2025. Cartagena, october 2, 3 and 4, 2025. pp. 385-393.

THE SURVEY OF COMPLEX ENVIRONMENTS FOR IMMERSIVE REALITY PROJECTS USING GAUSSIAN SPLATTING: THE SALA TERRENA OF THE SCUOLA GRANDE DI SAN MARCO

Maurizio Perticarini. University of Padua

Maurizio.perticarini@unipd.it

Via Francesco Marzolo 9, 35131, Padua, Italy

Francesca Condorelli. Free University of Bozen

Francesca.Condorelli@unibz.it

Piazza Università 1, 39100, Bozen, Italy

Andrea Giordano. University of Padua

Andrea.giordano@unipd.it

Via Francesco Marzolo 9, 35131, Padua, Italy

Abstract

This study aims to qualitatively analyze a method for acquiring a complex environment using integrated image-based techniques. These techniques combine well-established methodologies such as photogrammetry with Gaussian splatting algorithms, leveraging datasets obtained from a MILC camera and an Insta360 X4 spherical camera. The case study analyzed is the Sala Terrena of the Scuola Grande di San Marco in Venice, a space characterized by a double row of Corinthian columns and the complexity of the entrance portals of the adjacent rooms. The proposed approach involves an initial acquisition phase based on spherical videos to ensure complete spatial coverage, followed by a detailed survey phase focusing on the constructive details of elements of greater formal interest. This methodology allows for the advantages of both techniques to be fully exploited, preserving a high definition of constructive details while maintaining the perceptual quality of the environment in terms of global illumination, colors, materials, and reflections. The results highlight the benefits of this technological combination in terms of acquisition speed, reconstruction quality, and potential applications for immersive experiences. The resulting model is immediately usable in virtual reality environments without requiring a full reconstruction of the space, ensuring an engaging and realistic visual rendering.

Keywords integrated survey, photomodelling, gaussian splatting, immersive reality



XVII CONGRESO INTERNACIONAL
Expresión Gráfica Aplicada a la Edificación

APEGA CARTAGENA 2025

PENSAMIENTO GRÁFICO OCTUBRE
02 | 03 | 04

IL RILIEVO DI AMBIENTI COMPLESSI PER PROGETTI IN REALTÀ IMMERSIVA MEDIANTE GAUSSIAN SPLATTING: LA SALA TERRENA DELLA SCUOLA GRANDE DI SAN MARCO

Maurizio Perticarini. University of Padua

Maurizio.perticarini@unipd.it

Via Francesco Marzolo 9, 35131, Padua, Italy

Francesca Condorelli. Free University of Bozen

Francesca.Condorelli@unibz.it

Piazza Università 1, 39100, Bozen, Italy

Andrea Giordano. University of Padua

Andrea.giordano@unipd.it

Via Francesco Marzolo 9, 35131, Padua, Italy

Riepilogo

Questo studio si propone di analizzare qualitativamente un metodo per l'acquisizione di un ambiente complesso mediante tecniche integrate image-based. Tali tecniche combinano metodologie consolidate, come la fotogrammetria, con algoritmi di Gaussian Splatting, sfruttando dataset acquisiti tramite una fotocamera MILC e una fotocamera sferica Insta360 X4. Il caso studio analizzato è la Sala Terrena della Scuola Grande di San Marco a Venezia, uno spazio caratterizzato da una doppia fila di colonne corinzie e dalla complessità dei portali di ingresso degli ambienti adiacenti. L'approccio proposto prevede una fase iniziale di acquisizione basata su video sferici, finalizzata a garantire una copertura spaziale completa, seguita da una fase di rilievo dettagliato focalizzata sui particolari costruttivi degli elementi di maggiore interesse formale. Questa metodologia consente di sfruttare appieno i vantaggi di entrambe le tecniche, preservando un'elevata definizione dei dettagli costruttivi e al contempo mantenendo la qualità percettiva dell'ambiente in termini di illuminazione globale, cromie, materiali e riflessi. I risultati evidenziano i benefici di tale combinazione tecnologica in termini di rapidità di acquisizione, qualità della ricostruzione e potenziali applicazioni per esperienze immersive. Il modello risultante è immediatamente fruibile in ambienti di realtà virtuale, senza la necessità di una ricostruzione completa dello spazio, garantendo una resa visiva coinvolgente e realistica.

Parole chiave rilievo integrato, foto-modellazione, gaussian splatting, realtà immersiva

1. Introduction

Image-based surveying has undergone significant developments in recent years, following the application of AI algorithms in the processing and rendering of point clouds. One such algorithm, employed in the research presented here, is Gaussian Splatting (GS), which is widely used in video editing and demonstrates high potential for the construction of photorealistic immersive virtual environments, both for small-scale and large-scale scenarios. The specific composition of the output files allows for the visualization of reflections, lighting, and materials that would be impossible to obtain through conventional photogrammetric surveys. Moreover, the use of GS does not require the same quantity of photographic data typically necessary for photogrammetry, resulting in a significant optimization of acquisition time. Several studies have been conducted on this methodology, applied to urban, landscape, and architectural contexts, and exploring the use of various tools (Basso, Condorelli, Giordano, Morena, Perticarini, 2024; Perticarini, 2024; Lee, Lee, Lee, Park, Sim, 2024; Dalal, Hagen, Robbersmyr, Knausgard, 2024; Kerbl, Kopanas, Leimkühler, Drettakis, 2023). The objective of this research is to experiment with hybrid data acquisition techniques, using both a spherical camera and a mirrorless camera, to generate an immersive environment representing a complex space characterized by a large hall articulated by Corinthian columns and a series of architectonic elements defined by intricate moldings. The case study is the Sala Terrena of the Scuola Grande di San Marco in Venice, surveyed as part of the 2023 FSE project of the Veneto Region, entitled Re-life: accessibility and inclusivity in the scenarios of reuse and enhancement of former monastic buildings, carried out by the University of Padua and the Iuav University of Venice. The site was selected due to its inclusion in the architectural complex of the Monastery of Ss. Giovanni e Paolo, one of the central themes of the broader research project. This study, although transversal to the aforementioned research project, aims to explore new opportunities offered by the GS technique in the development of immersive environments. The work follows a precise workflow, grounded in a thorough review of the current state of the art in data processing, and especially with regard to data management and visualization. Software platforms such as Unreal Engine and web-based environments like PlayCanvas are progressively evolving to interpret this type of file with increasing fidelity, leading to a novel approach to the creation of virtual environments and applied games for cultural heritage dissemination.

1.1. The case study

Crossing the main entrance of the Scuola Grande di San Marco, one enters a ground-floor reception hall, referred to both as the Sala Terrena and as the Portego delle Colonne (Guidarelli, 2017). This space is articulated into three longitudinal aisles by two symmetrical rows of Corinthian columns, set on tall plinths made of Istrian stone. Following the fire that damaged the building, Gregorio di Antonio da Padova undertook the construction of the foundations for the new load-bearing system, while the architectural and decorative apparatus of the columns and pedestals was subsequently completed by Pietro Lombardo and Giovanni Buora, who executed the sculptural work with remarkable formal refinement. During the 1490s, the architectural definition of the ground floor was initiated, following a project that passed from Pietro Lombardo to Mauro Codussi. In this context, the installation of the flooring was carried out by Domenico Moro and the stonecutter Giovanni De Mario, craftsmen also known for their contemporary work in the church of San Zaccaria. The flooring is distinguished by its compositional complexity and the illusionistic effect produced by the calibrated use of stone materials from various origins—Rosso Verona, Istrian stone, and in all likelihood Ligurian slate—combined to create perspectival motifs in the form of three-dimensional cubes. Natural lighting of the space is provided by ten large round-arched windows positioned along the western façade, which confer a diffused

luminous quality and highlight a sequence of commemorative marble plaques dedicated to the principal benefactors of the Scuola. On the exterior, these openings alternate rhythmically with pilasters decorated with sculpted roundels depicting members of the brotherhood, serving as important elements of identity and recognition. Finally, two openings along the right-hand wall of the hall lead to the monumental staircase, consisting of a double ramp with an intermediate landing, connecting the Sala Terrena with the Sala Capitolare above, thereby emphasizing the hierarchical and functional continuity between the two levels of the building (Fig. 1).



Fig. 1. Wide-angle photograph of the Sala Terrena of the Scuola Grande di San Marco in Venice

2. Methodology

The environment was surveyed using the spherical camera Insta360 X4, which was employed to record an 8K equirectangular-resolution video. To capture the video, the camera was mounted on a 1-meter-long selfie stick, allowing for stable placement of the device above the operator's head. Proceeding with a slow and steady pace, a pre-planned path was followed to ensure coverage of the entire space, including all sides of the Corinthian columns and the architectural details of the various portals located on two of the hall's walls. The camera's elevated point of view allowed for effective framing of both the flooring and the wooden ceiling. The video, originally recorded in Insta360's proprietary .insv format, was subsequently processed using InstaStudio software, which enables conversion from dynamic video to an equirectangular projection format, exported as a 7680×3840 pixel .mpeg4 file (Fig. 2). A crucial part of the adopted methodology was the segmentation of the video into frames. To achieve optimal results, an entirely open-source approach can be followed, exploiting the output capabilities of DaVinci Resolve (a widely used video editing software), which enables the rapid conversion of video into a sequence of raster-format frames at a chosen regular interval. It is important to note at this point that the software used for GS-based survey processing, Jawset PostShot (version 0.6 beta released on April 22, 2025), is not yet capable of correctly interpreting equirectangular images, which are typically produced from 360° photos or videos. Hence, the core of the methodology described here lies in the additional subdivision of the spherical images into quadrants (Jamil O, 2025; Rangelov, Waanders, Waanders, Keulen, & Miltchev, 2025).

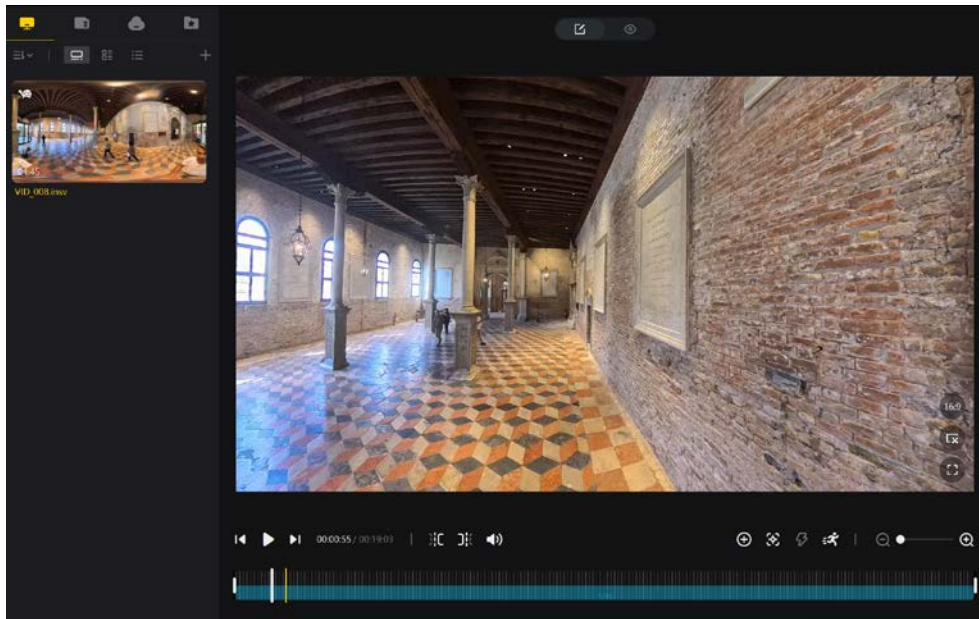


Fig. 2. Processing of the 360° video in InstaStudio

The process is carried out using a code block included in the open-source software Meshroom, a program used for traditional photogrammetry that operates through the now widely adopted visual node-based programming approach. Meshroom features a specific node that enables the division of a 360° video into multiple zones (or viewpoints). This node, called “split360images,” easily performs this function once executed, by taking spherical images as input and splitting them as output according to the number of divisions specified within the corresponding parameter (in the described case, the images were divided into four viewpoints per frame) (Fig. 4).

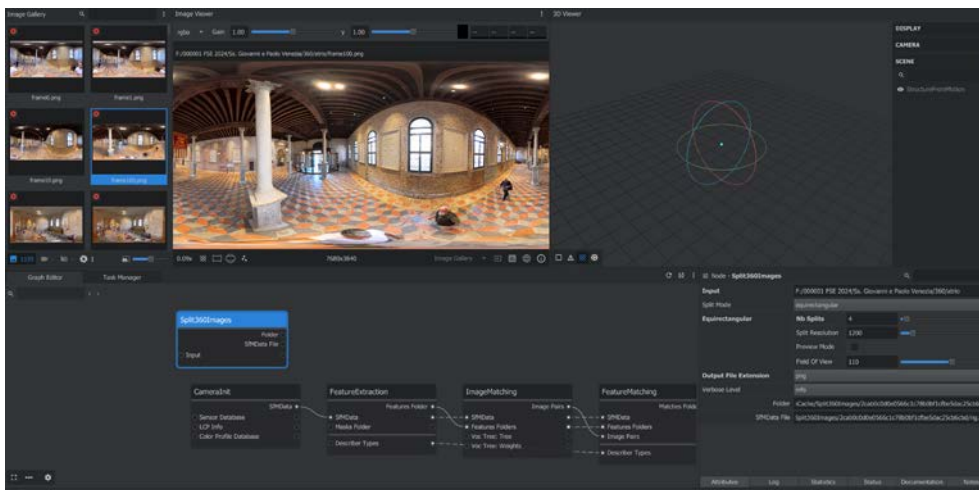


Fig. 3. Processing frames with the split360images node in Meshroom

Once a complete dataset of images—each corresponding to the four main directions for every frame—has been obtained, it can be imported into the PostShot software. Approximately 70 equirectangular frames were used which, after being divided into 4 portions each, resulted in about 280 images (Fig. 4–5). The software uses an SfM algorithm to align the images within the three-dimensional space and subsequently generate a sparse point cloud enriched by characteristic ellipsoids, which are typical of GS-based reconstructions. As shown in Figure 6, the

resulting 3D scenario is already rich in detail, presents no significant gaps, and is well-suited for visualization on various interactive platforms. In order to further enhance the level of detail in the most complex and distinctive architectural elements of the opulent hall, additional GS-based reconstructions were carried out for the portals and the Corinthian capitals of the two rows of columns, using standard images captured with a mirrorless camera, processed within the same software environment to generate corresponding point clouds..



Fig. 4 - 5. On the left, the original dataset composed of equirectangular frames; on the right, the dataset processed with split360images

2.1. Management and editing of 3dgs files

The .ply file of the GS-based point cloud of the environment was merged with the point clouds generated from the surveys of the constructive details of the architectural archetypes (Fig. 7) and was cleaned of unnecessary points not relevant for visualization. In addition to the management tools offered by the PostShot software, the web platform Supersplat by PlayCanvas proved useful for cloud cleaning, thanks to its intuitive interface. The new "Splat3" radiance field profile introduced in the latest release of PostShot software demonstrates improved performance both in processing time and in the rendering of details. As shown in Figure 7, the detail of the portal already reveals a considerable level of definition after just 30 ksteps of processing.

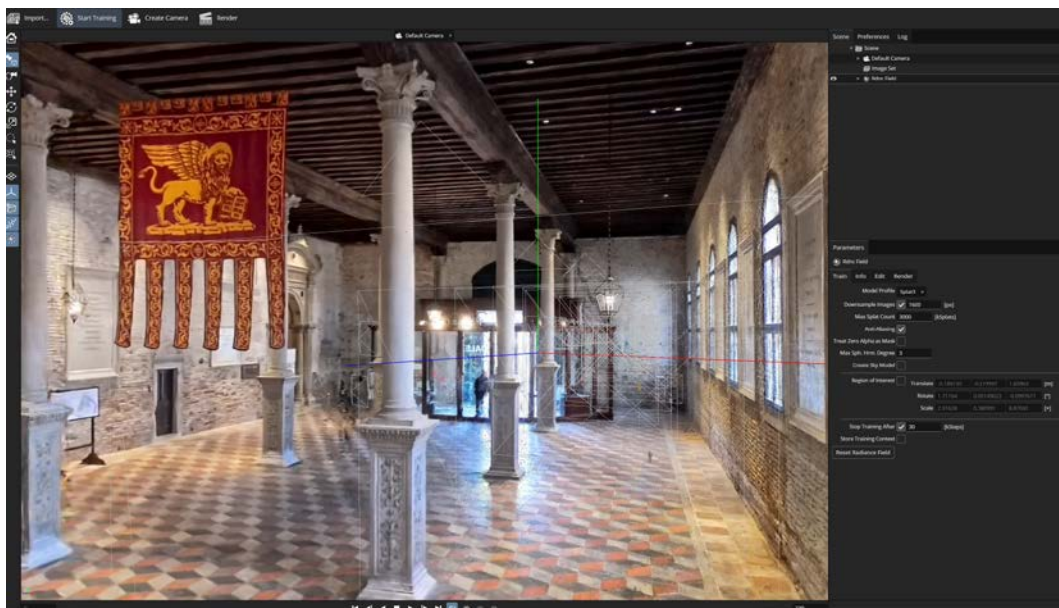


Fig. 6. Result of the processing in PostShot

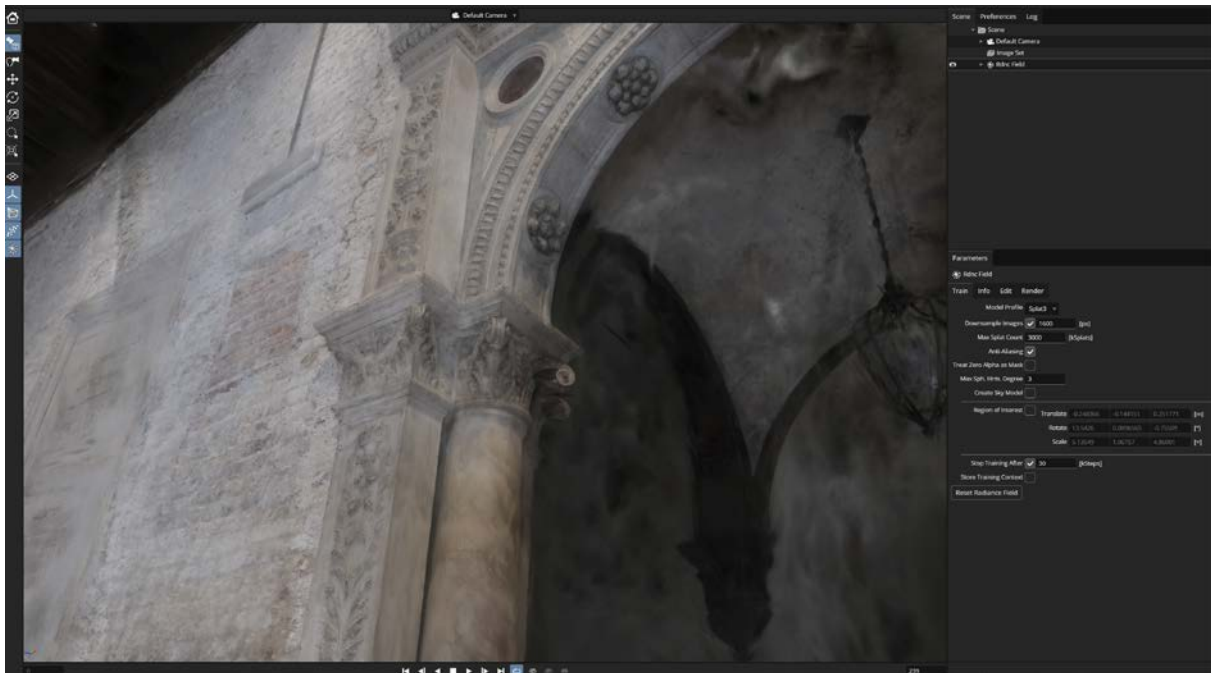


Fig. 7. Result of the processing in PostShot – detail of the entrance portal to the main staircase of the Scuola Grande di San Marco

3. Unreal Engine 5 and the processing of immersive reality

The .ply file is imported using the PostShot plugin, which enables seamless integration with Unreal Engine. The scene is placed within a dedicated level, prepared for first-person or VR navigation. After importing the dataset, the three-dimensional environment is optimized through a calibrated lighting configuration to ensure perceptual coherence within the immersive experience. Considering that Gaussian Splatting is based on radiance fields and does not involve an explicit mesh with defined normals, the scene's illumination is not handled through conventional methods but is instead rendered via the interpolation of the intrinsic radiometric properties of the Gaussians themselves. To achieve visual integration with Unreal Engine's native components, dynamic light sources and atmospheric volumes (atmospheric fog) were added, aimed at blending the survey-derived portions with the surrounding environment. A hybrid approach was therefore adopted: on one hand, the Gaussian entities preserve the original radiometric information; on the other, global illumination is used to modulate shadows and reflections on objects, enhancing the credibility of the virtual scene. One of the critical aspects of using Gaussian Splatting in interactive environments lies in the absence of explicit surface geometry. To make the scene navigable in Unreal Engine 5, simplified colliders were generated from a mesh derived from the same source dataset. This mesh, which is not visible at runtime, functions as a collision surface and a support for physical interaction within the virtual world. The collider system was optimized to enable first-person navigation, supporting physical simulation and interaction with elements in the scene. This approach allows for leveraging the visual quality of Gaussian representations without sacrificing the spatial and physical consistency required for a believable immersive experience (Palestini, Basso, Perticarini, 2022; Perticarini, 2024).



Fig. 8. Screenshot of the immersive environment in Unreal Engine 5

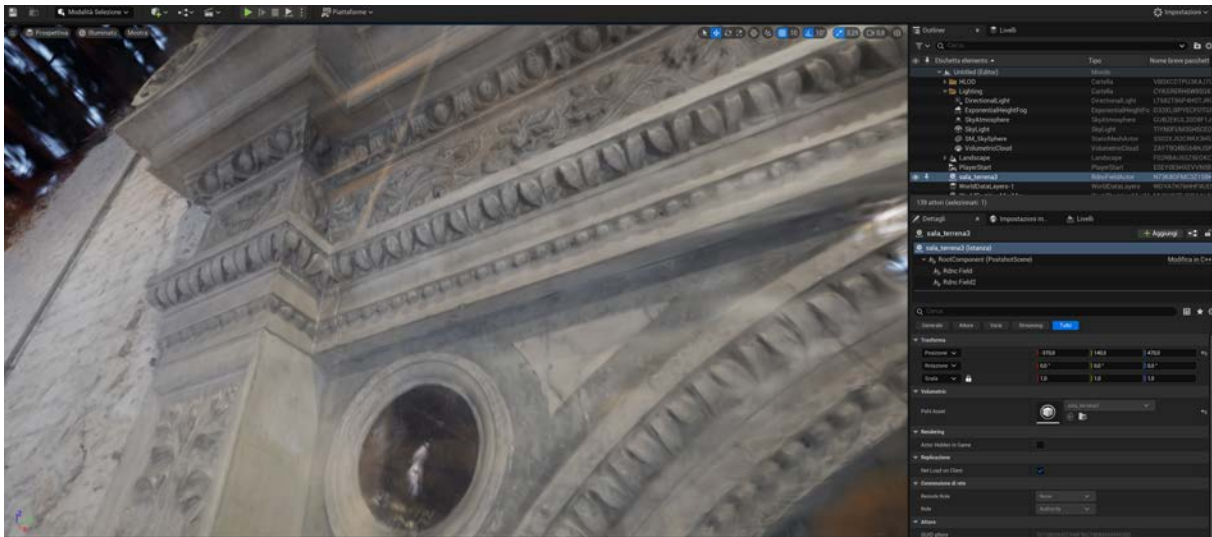


Fig. 9. Screenshot of a close-up view in the immersive environment in Unreal Engine 5

4. Conclusions

The conducted experimentation has demonstrated that Gaussian Splatting (GS) constitutes an effective approach for the generation of photorealistic immersive environments based on image-based data, surpassing traditional photogrammetric methods in terms of acquisition efficiency and visual rendering. The reduction in the number of required photographs and the ability of Gaussians to encode radiometric properties made it possible to achieve optimal results with reduced processing times. The integrated application of open-source workflows (Meshroom, DaVinci Resolve), combined within the Unreal Engine 5 development environment, enabled a hybrid workflow capable of combining visual fidelity with real-time interactivity. In particular, despite the results achieved, some critical issues remain: the current inability of PostShot (v. 0.6 beta) to directly read 360° equirectangular formats; and the absence of output meshes, which requires the creation of collision geometries.

Bibliographic references

Basso, A., Condorelli, F., Giordano, A., Morena, S., Perticarini, M. (2024). Evolution of rendering based on radiance fields: The Palermo case study for a comparison between NeRF and Gaussian Splatting. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-2/W4-2024, 57–64. <https://doi.org/10.5194/isprs-archives-XLVIII-2-W4-2024-57-2024>.

Dalal A, Hagen D, Robbersmyr KG, Knausgard KM. (2024). Gaussian splatting: 3D reconstruction and novel view synthesis, a review. *IEEE Access*.

Guidarelli G. (2017). L'architettura della Scuola Grande di San Marco. In Ortalli G, Settis S (a cura di), *La Scuola Grande di San Marco a Venezia* (pp. 43–66). Panini, Modena.

Jamil O, Brennan A. (2025). Immersive heritage through Gaussian splatting: A new visual aesthetic for reality capture. *Frontiers in Computer Science*, 7. <https://doi.org/10.3389/fcomp.2025.1515609>

Kerbl, B., Kopanas, G., Leimkühler, T., Drettakis, G.: 3D Gaussian Splatting for Real-Time Radiance Field Rendering. *ACM Transactions on Graphics*, 42(4), Article 139, pp. 1–14, <https://doi.org/10.1145/3592433> (2023).

Lee J, Lee S, Lee J, Park J, Sim J. (2024). GScore: Efficient radiance field rendering via architectural support for 3D Gaussian splatting. In *Proceedings of the 29th ACM International Conference on Architectural Support for Programming Languages and Operating Systems, Volume 3 (ASPLOS '24)* (Vol. 3, pp. 497–511). Association for Computing Machinery, New York, NY, USA. <https://doi.org/10.1145/3620666.3651385>

Palestini, C., Basso, A., Perticarini, M. (2022). 3D modeling from UAV for the reconfiguration of oxidation systems in Abruzzo: The case of the Tower of Forca di Penne, an immersive archival resource for the lost historical heritage. In S. Parrinello, S. Barba, A. Dell'Amico, A. di Filippo (Eds.), *D-SITE: Drones—Systems of information on cultural heritage for a spatial and social investigation* (Vol. 2).

Perticarini, M. (2024). Innovative techniques for the survey of objects no longer accessible and not measurable. In F. Bergamo, A. Calandriello, M. Ciammaichella, I. Friso, F. Gay, G. Liva, C. Monteleone (Eds.), *Measure/out of measure: Transitions. Proceedings of the 45th International Conference of Representation Disciplines Teachers* (pp. 1895–1902). FrancoAngeli. <https://doi.org/10.3280/oa1180-c565>.

Perticarini M. (2024). *Machine learning and mixed reality for the enhancement of cultural heritage: The Monastery of Saints Severino and Sossio case study*. Springer. ISBN: 978-3031712869.

Rangelov, D., Waanders, S., Waanders, K., Keulen, M. v., & Miltchev, R. (2025). Impact of Data Capture Methods on 3D Reconstruction with Gaussian Splatting. *Journal of Imaging*, 11(2), 65. <https://doi.org/10.3390/jimaging11020065>