3D Gaussian Splatting in Reality Capture Workflows

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Introduction & Context

Unmanned Aerial Systems (UAS) and close-range reality capture workflows have traditionally relied on Structure-from-Motion (SfM) followed by Multi-View Stereo (MVS) reconstruction to generate detailed 3D models of scenes and objects. These workflows often complement terrestrial laser scanning (TLS) for applications requiring high geometric precision. While these established methods excel at producing geometrically accurate representations, they face challenges with certain surface materials and conditions that defeat traditional feature-matching algorithms (Bartos *et al.*, 2023). Geometric reconstruction is not always the primary objective of reality capture. Applications prioritizing visual context over high accuracy span multiple sectors (Boardman and Bryan, 2018, and Radanovic *et al.*, 2020):

Figure 1. 3DGS reconstruction of the Legislative Services Building (historically known as the Colorado State Museum, built 1915) from gimballed smartphone video. Note the fine architectural detail captured in the ornamental railings and the photorealistic rendering of reflective glass windows, demonstrating 3DGS capabilities for heritage documentation.

- Digital twins
- Heritage and cultural: documentation, restoration, exhibitions, virtual tours, archaeological recording, Figure 1.
- Property and facilities: real estate marketing, facility/asset management, insurance assessments
- Planning and response: conservation planning, public engagement, emergency response

3D Gaussian Splatting (3DGS) is a fundamentally different approach to 3D scene reconstruction, addressing many of these limitations (Kerbl *et al.*, 2023). Rather than replacing traditional photogrammetric methods or TLS, 3DGS serves as a complementary technology that fills a persistent gap in 3D scene representation. This gap reflects the trade-off where practitioners often choose between geometric precision and rich visual context for stakeholder communication and analysis (Radanovic *et al.*, 2020).

Digital twin applications in smart cities and infrastructure management could benefit from the visual fidelity and real-time rendering capabilities of 3DGS.

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How 3D Gaussian Splatting Works

3DGS represents scenes using millions of 3D Gaussian primitives. These are basic geometric building blocks shaped like jellyfish bells, each parameterized by mean position (its center or origin in 3D space), covariance (shape and stretch), opacity (how solid or transparent it looks), and spherical harmonic coefficients (color from different angles) (Kerbl *et al.* 2023). These shapes appear differently depending on the viewpoint (they are view-dependent), so capturing images from multiple angles is needed for optimal results (Kerbl *et al.* 2023). When rendered, the primitives blend together as smooth, overlapping blobs to create a continuous volumetric representation. The primitives distribute wherever needed to reproduce scene appearance, not just on surfaces. Unlike traditional mesh-based reconstruction that seeks discrete surface points through feature matching, 3DGS optimizes volumetric representations that can capture semi-transparent materials and surfaces lacking enough texture for reliable keypoint (distinctive points like corners and edges that can be identified at different scales by their size and shape) detection (Wolf *et al.*, 2014).

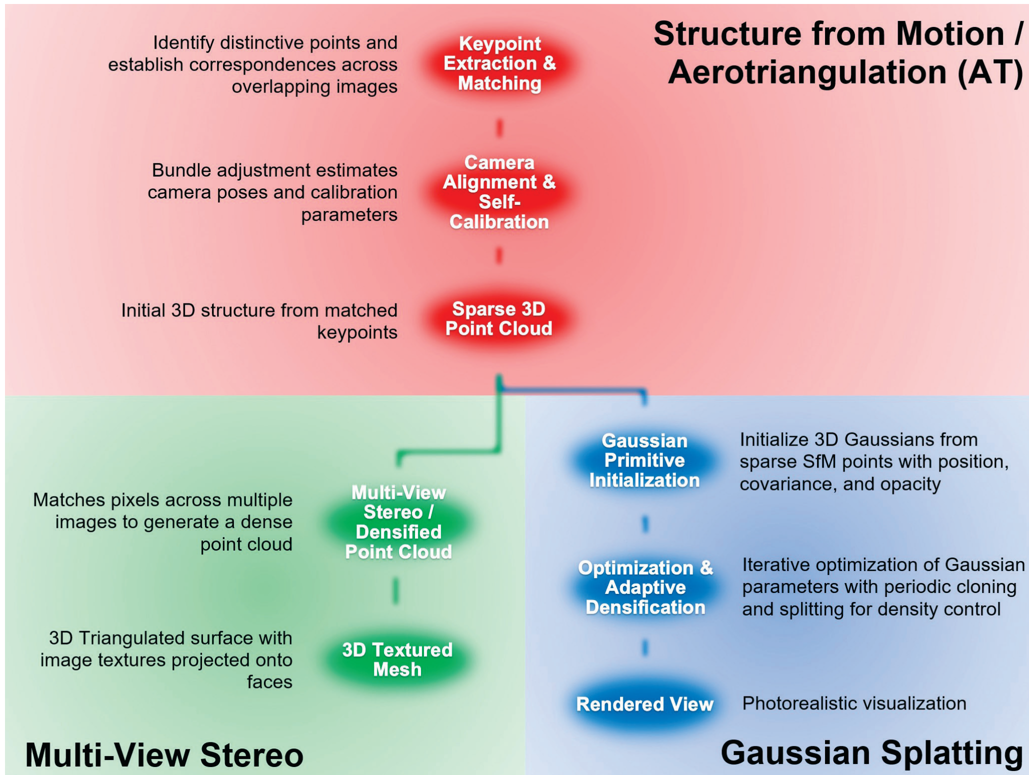

Figure 2. Comparison of traditional photogrammetric and 3DGS reconstruction workflows.

The method shares initialization with traditional workflows, beginning with SfM-derived sparse point clouds and camera poses, Figure 2, (Kerbl *et al.* 2023). Instead of pursuing geometric accuracy through dense correspondence matching, 3DGS optimizes for visual quality by making the rendered scene look as close as possible to the captured images (Kerbl *et al.* 2023). This difference in optimization objectives allows the method to excel where traditional approaches may struggle. Like traditional methods, 3DGS performance depends on adequate lighting and image quality.

3DGS demonstrates reliable reconstruction capabilities in complex scenarios while offering processing performance benefits compared to traditional MVS methods (Petrovska and Jutzi, 2025).

Practical Examples

Two practical examples demonstrate 3DGS capabilities with challenging subjects that typically require specialized equipment or workflows for traditional photogrammetric reconstruction.

Military medals present significant reconstruction challenges due to highly reflective metallic surfaces, complex ribbon textures, and intricate relief details, Figure 3. Traditional photogrammetric approaches typically require cross-polarized lighting to manage specular reflections from metallic surfaces (Bartos *et al.*, 2023). However, 3DGS reconstruction from smartphone video (iPhone 13 on gimbal) captured while orbiting the subject at multiple angles produced surprising results. The reconstruction captured individual threads in fabric ribbons, fine surface details on the medals, and even the suspension thread used to hang the medals during capture. The reflective metallic surfaces, which challenge traditional MVS dense matching algorithms, rendered with photorealistic quality in the 3DGS output.

Figure 3. 3DGS reconstruction of military medals from smartphone video showing detailed ribbon texture and reflective metallic surface rendering.

A small industrial facility demonstrates 3DGS performance under deliberately challenging field conditions designed to stress traditional methods. The scene included multiple difficult-to-reconstruct elements, Figure 5:

- Reflective metal panels
- Glass windows
- Fine cables and piping
- Complex shadows from low sun angle conditions typical of high-latitude winter acquisition

A single three-minute smartphone video captured three orbital passes at different heights (ground level, eye level, and elevated with selfie stick extension) using a gimbal for stabilization. The low sun angle produced lens flare, and individual frames extracted from the video provided lower resolution imagery compared to still photography, further challenging keypoint detection and correspondence matching for SfM-MVS reconstruction algorithms.

Traditional SfM-MVS processing required sky masking to achieve successful dense point cloud and mesh generation yet produced significant noise artifacts on the reflective roof surface. 3DGS processing required no additional image preprocessing and completed more rapidly while producing superior visual results. Figure 4 shows all three outputs (3D textured mesh, point cloud, and 3DGS) georeferenced to the same location in ArcGIS Pro, demonstrating a multilayered approach where different reconstruction methods provide complementary information (Radanovic *et al.*, 2020).

Although the point cloud and mesh quality are affected by the intentionally challenging acquisition conditions, the comparison demonstrates 3DGS capabilities for rapid field documentation where traditional workflows encounter difficulties with challenging surface properties and suboptimal lighting conditions.

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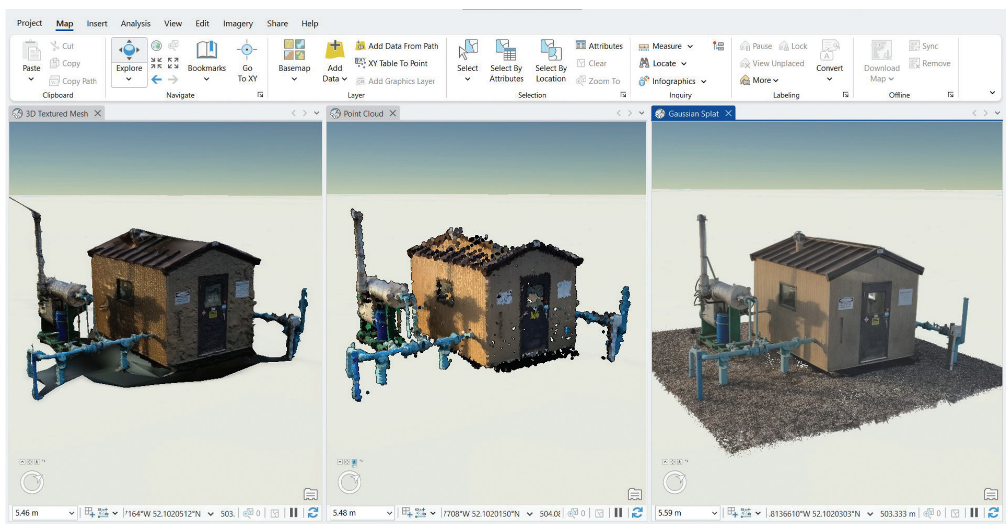

Figure 4. Comparison of 3D textured mesh, point cloud, and 3DGS outputs georeferenced in ArcGIS Pro, demonstrating complementary reconstruction methods.

Figure 5. 3DGS rendering of an industrial scene showing photorealistic reconstruction of reflective surfaces, glass, cables, and piping from smartphone video.

Applications and Implementation

Traditional SfM-MVS workflows and TLS remain optimal for applications requiring high accuracy, dimensional analysis, and CAD or BIM integration, while 3DGS provides value when photorealistic visualization and stakeholder communication are critical project objectives (Radanovic *et al.*, 2020, and Petrovska and Jutzi, 2025). Heritage documentation represents a compelling use case where this balance matters, Figure 1. Effective communication of heritage assets requires more than raw geometric data, demanding capabilities in 3D modeling, animation, and presentation to convey true appearance and condition (Boardman and Bryan, 2018). Realistic texture increases visual fidelity and holds additional valuable information that may not be captured in purely geometric reconstructions (Radanovic *et al.*, 2020). Similarly, applications including insurance assessments, public engagement initiatives, and emergency response benefit from realistic damage visualization and accessible representations that support decision-making across diverse stakeholder groups.

Traditional photogrammetric methods and TLS face challenges with certain surface properties or conditions. Industrial inspection workflows may encounter difficulties with highly polished surfaces, intricate geometries, and materials lacking sufficient texture for reliable keypoint detection. TLS faces challenges with mirror-like surfaces, glass, and materials with low infrared reflectivity that cause signal dropout. Simple video capture from varying viewpoints provides an accessible approach for 3DGS generation in these scenarios, with results further enhanced using higher resolution video or Digital Single-Lens Reflex (DSLR) or mirrorless cameras. The volumetric representation approach of 3DGS can capture these challenging surfaces where both traditional methods and TLS may produce incomplete reconstructions.

This capability extends to complex vegetated scenes. 3DGS constructs geometry behind vegetation occlusion addressing challenges where SfM and MVS struggle with overlapping foliage and irregular plant geometries (Petrovska and Jutzi, 2025). The technology demonstrates potential for forestry applications, allowing canopy reconstruction, biomass estimation and agricultural monitoring (Petrovska and Jutzi, 2025).

Workflow Integration

Hybrid approaches represent the most practical implementation strategy. Instead of replacing traditional SfM-MVS or TLS, 3DGS integrates as a complementary visualization tool. Organizations with established SfM workflows can incorporate 3DGS as an additional processing step using the same input imagery and camera calibrations (Kerbl *et al.*, 2023). This approach minimizes disruption to proven workflows while adding enhanced visualization capabilities. Integration uses TLS point clouds as the main geometric framework, while SfM camera poses and 3DGS optimization provide photorealistic surface representation. 3DGS outputs can be georeferenced and measured, enabling direct integration with traditional survey data. The combined workflow and presentation delivers technical accuracy and immersive visualization within a single project framework.

Future Applications

The rapid development of 3DGS technology suggests expanding applications in photogrammetry and remote sensing. Real-time monitoring applications represent a particularly promising direction, where the fast-rendering capabilities of 3DGS could enable immediate visualization of changing conditions for construction monitoring, environmental assessment, and emergency response scenarios (Kerbl *et al.*, 2023).

Digital twin applications in smart cities and infrastructure management could benefit from the visual fidelity and real-time rendering capabilities of 3DGS (Kerbl *et al.*, 2023). The technology's ability to provide photorealistic visualization of scenes while maintaining reasonable processing requirements makes it well-suited for applications requiring frequent updates and broad stakeholder access.

The integration of 3DGS with established surveying and mapping workflows appears likely to expand as the technology matures and implementation tools become more accessible to the broader geospatial community. Research directions in improved geometric accuracy suggest that current limitations may be addressed through continued technological development.

The evolution from academic research to practical implementation is demonstrated by major industry adoption, with companies including Bentley Systems, Esri, GeoCue, Pix4D, and others implementing 3DGS support in their platforms. This indicates that 3DGS is transitioning from an experimental technique to a viable complementary tool for photogrammetric workflows (Petrovska and Jutzi, 2025). This transition follows the typical pattern of remote sensing technologies, beginning with specialized research applications and gradually expanding to broader professional practice as tools and workflows mature.

Author

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