Gaussian Splatting & XR

Loren Ybarrondo

June 28th, 2025

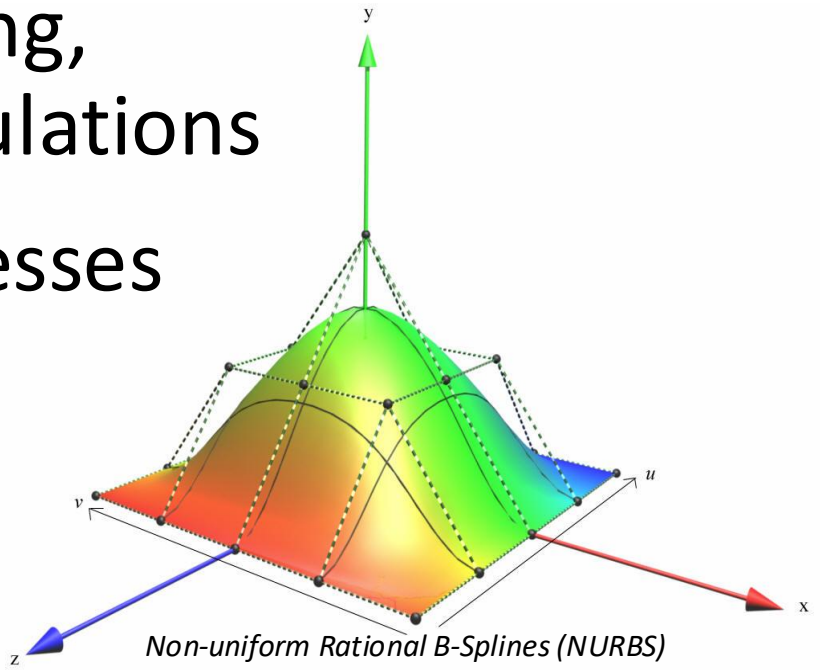
Topics

- The Traditional 3D Graphics Pipeline
- Classical Ray Tracing: Foundation for SfM
- PTGui & SfM – “Adjacent workflows”
- Structure-from-Motion (**SfM**)
- SfM as the First Step of Gaussian Splatting (**GS**)
- What is a Gaussian Splat?
- How SfM Points Become a 3D Scene of Splats
- Let’s Go Splatting

The Traditional 3D Graphics Pipeline

The Utah Teapot, Newell (1975)

- Complex modeling, lighting, shading, & texturing calculations
- Multiple stages and processes
- **Pixel-perfect accuracy**
- **Real-time rendering** by exotic GPUs (e.g., RTX+)
- Powerful, but intensive and inflexible

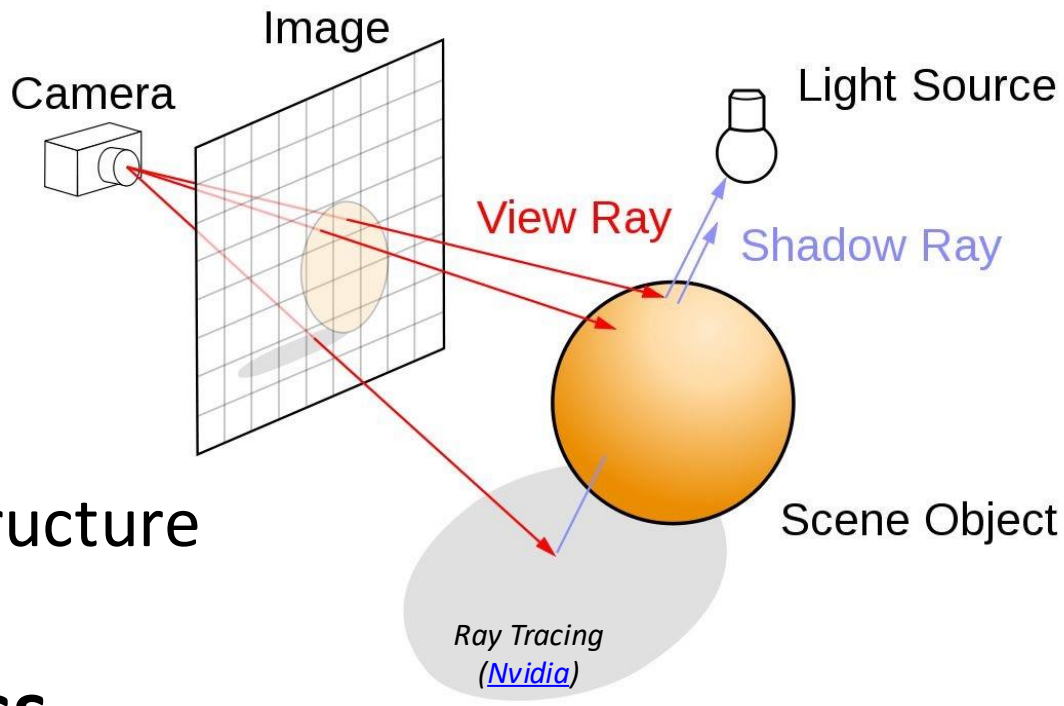


Non-uniform Rational B-Splines (NURBS)

Classical Ray Tracing: A Foundation for SfM

"An Improved Illumination Model for Shaded Display", Whitted (1979)

- Ray tracing projects **3D geometry → 2D pixels**
- Camera is fixed, scene is known

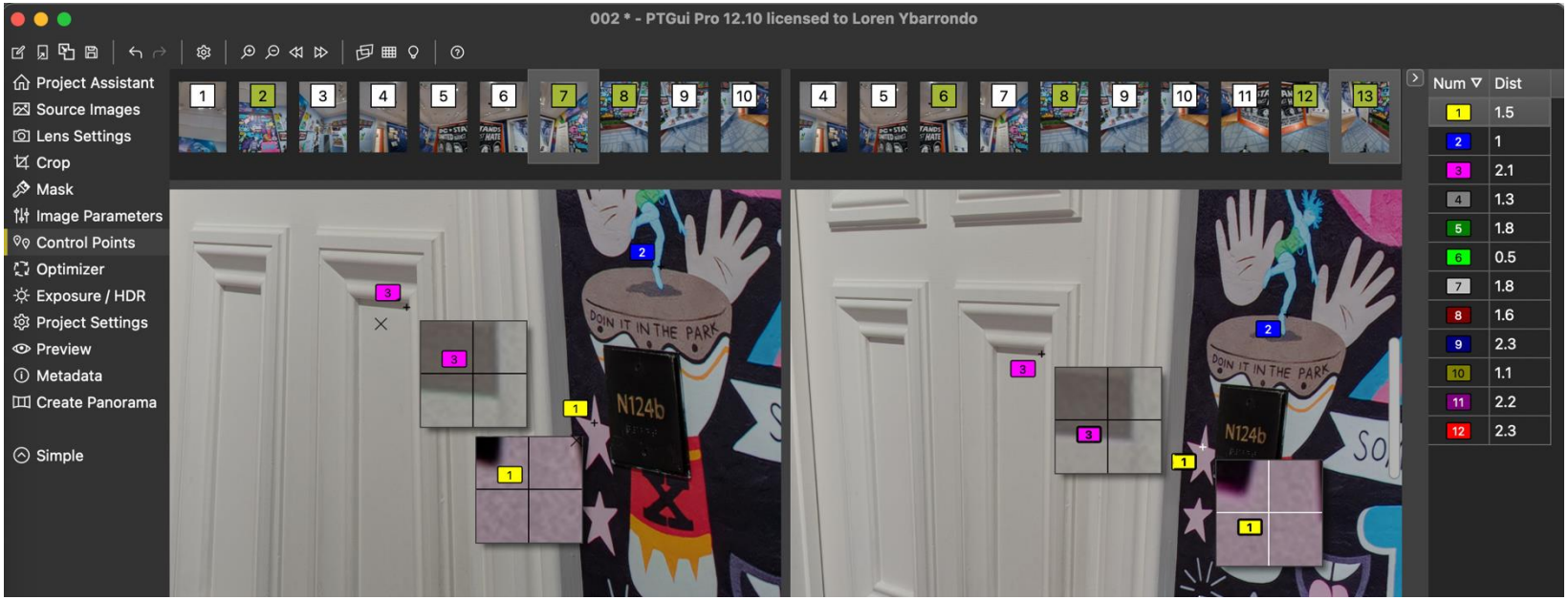


SfM reverses this:

- From 2D pixels → 3D Camera path & structure
- Foundation of **photogrammetry** & **GS**

PTGui & SfM – Shared Foundations

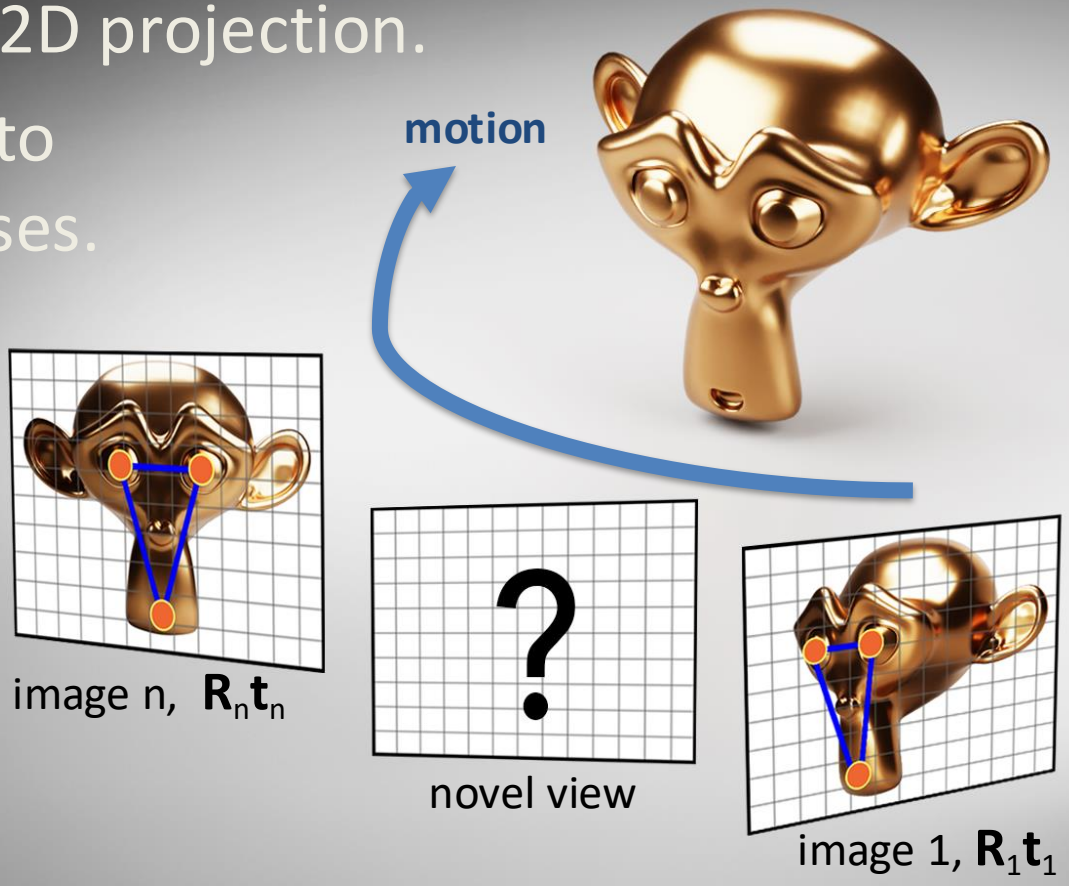
PTGui (Panorama Stitching)	Structure-from-Motion (SfM)
Control Point (2D-2D pixel match)	Match 3D features across multiple images
Seamlessly align 2D images	Triangulate 3D points & solve for camera ‘movement’
Manual or automatic using SIFT?	Automatic using algorithms like SIFT, ORB
Result: Flattened stitched image	Result: Sparse 3D point cloud & camera positions



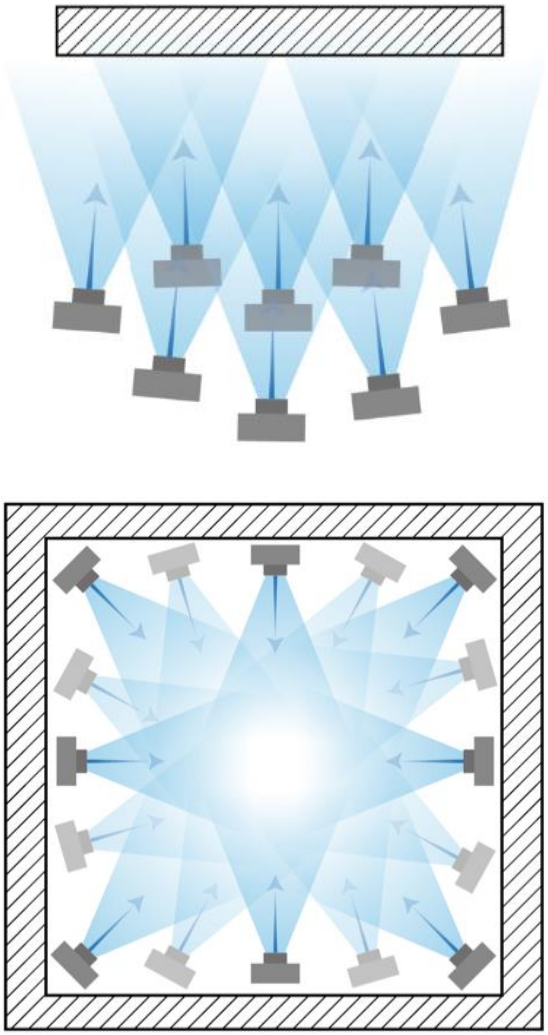
Control Point Detection (PTGui)
Likely a variant of Scale-Invariant Feature Transform, (SIFT)

Structure-from-Motion (SfM)

- Feature matching finds identical points across multiple images taken of a 3D space or object.
- In stitching (e.g., PTGui), these are used to align images onto a shared 2D projection.
- In SfM, they are used to determine camera poses.
- As the camera moves, parallax reveals depth & 3D structure.



Scanning Objects & Spaces



(from Autodesk)

Fill the Frame: Keep subject ~60% of image; use consistent lighting and shoot in RAW.

Ensure High Overlap: Aim for 70% front/side overlap—each point must be in multiple images.

Use Quality Gear: High-res camera + prime lens; stabilize with tripod to avoid motion blur.

Focus & Aperture: Use narrow aperture for full depth; avoid blur, auto settings, or artifacts.

Plan a Capture Path: Circle target at multiple heights and angles for full coverage.

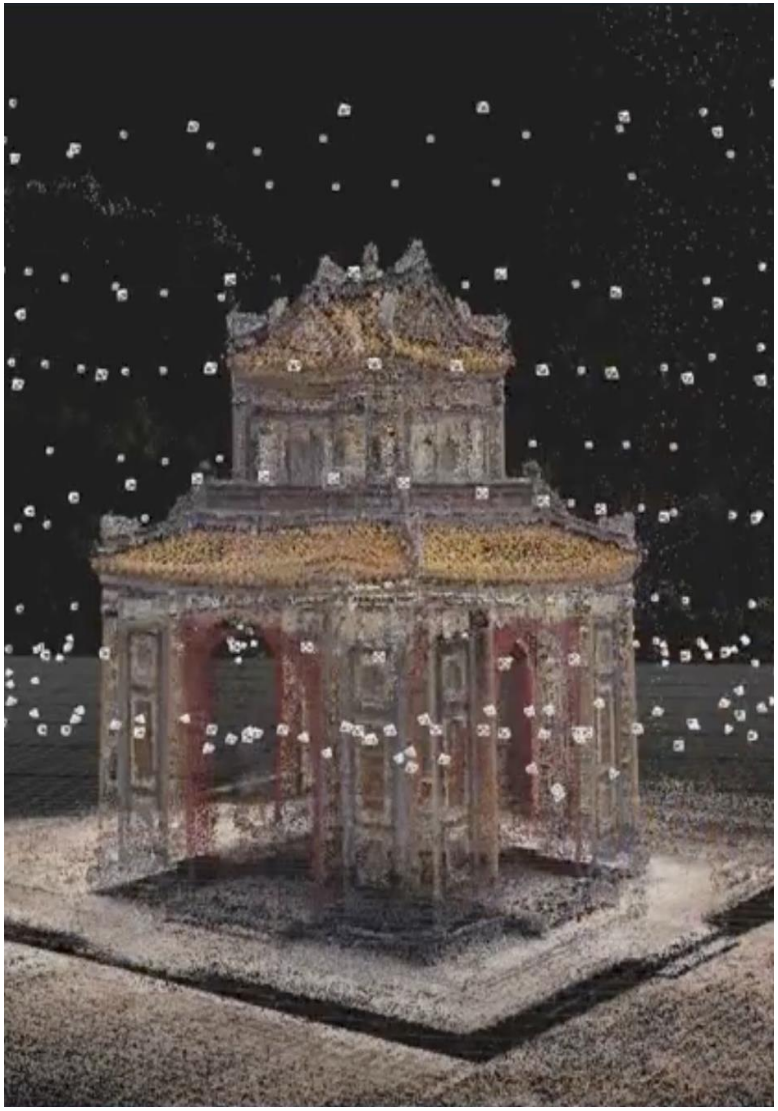
Handle Challenging Surfaces: Matte spray helps with reflections; textures surfaces scan best.

Capture Generously: Take more images than needed—discard only flawed shots later.

Pan Instead: Unlike VR photography about a nodal point, move sideways & minimize rotation.

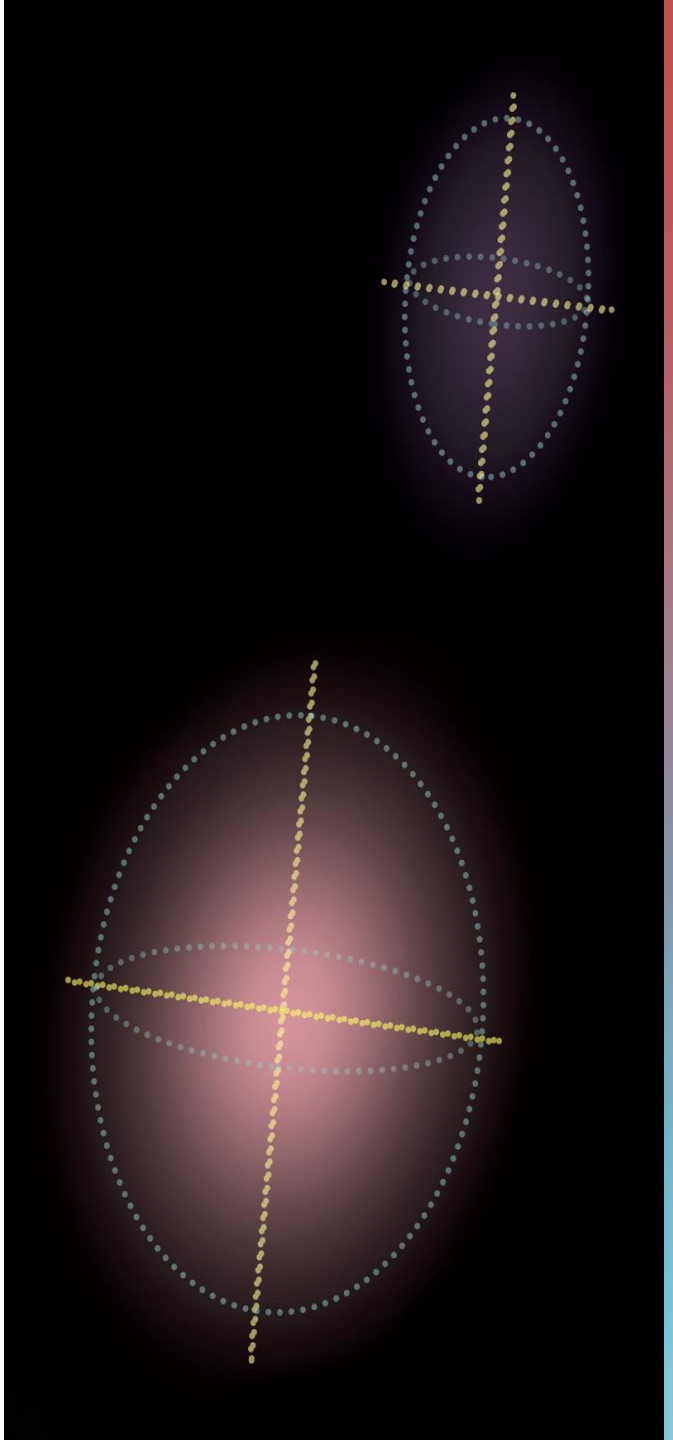
From SfM to Gaussian Splatting

- Begin with a photogrammetry scan → sparse point cloud + camera poses
- Initialize one 3D Gaussian splat per point
- Splat refinement is iterative:
  - Uses visibility-aware optimization across views
  - Splats are split and adjusted to better match observed geometry (in source images)
- Final result: A dense cloud of view-dependent ellipsoids



The Gaussian Splat: A Smarter Point Cloud*

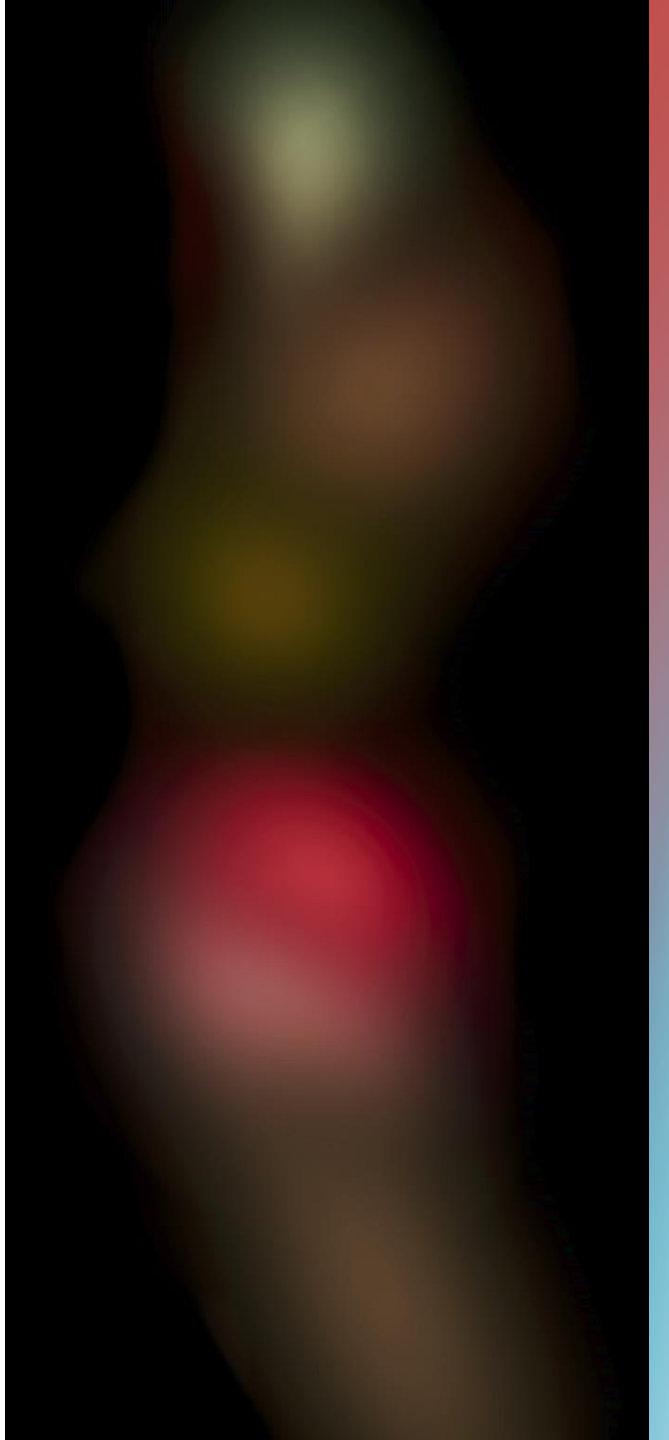
- Each splat is a 3D anisotropic Gaussian ellipsoid, not just a point
- Defined by **16 parameters**:
  - Position (x, y, z)
  - Shape & orientation (covariance matrix)
  - Color (R, G, B) and opacity
- **View-dependent**: appearance changes based on camera angle
- Enables **real-time rendering**—no mesh needed
- *Recognize from Photoshop?*



**It's all about triangles now. (see resources)*

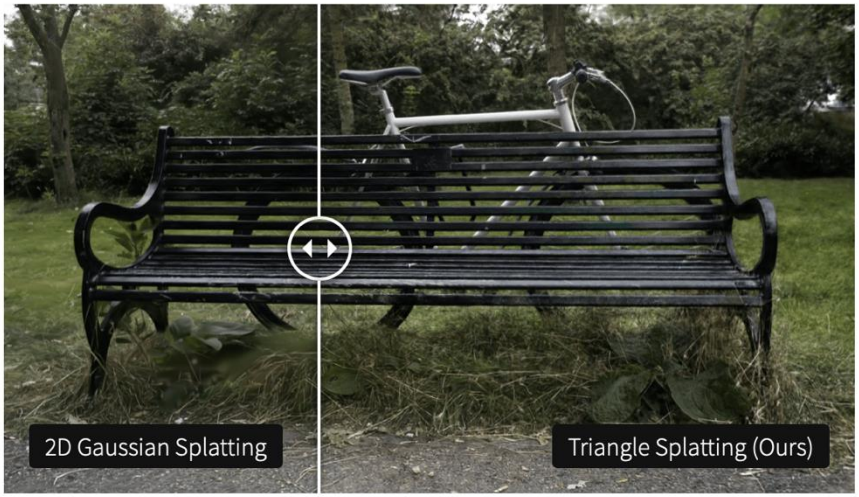
Refining Gaussian Splats With AI

- AI training adjusts each splat to better match source photos
- Optimization improves:
  - **Position:** precise alignment to scene geometry
  - **Covariance:** anisotropic shape & orientation of the splat
  - **Color & Opacity:** adjusted for realistic appearance from multiple views
- Splats are **split and evolved** over time to increase detail (**by AI**)
- Final output: dense cloud of view-optimized ellipsoids



How We Measure Rendering Accuracy

Metric	What It Measures	Purpose
LPIPS (Learned Perceptual Image Patch Similarity)	Perceptual similarity between rendered and real images	Captures visual quality as perceived by humans
SSIM (Structural Similarity Index)	Structure, contrast, and brightness	Evaluates structural fidelity between render and ground truth
PSNR (Peak Signal-to-Noise Ratio)	Pixel-level difference	Measures raw image fidelity and error



(Triangle Splatting for Real-Time Radiance Field Rendering)

GS Tools

Applications, (mobile & desktop)

Scaniverse, RealityScan, Polycam, postshot, Splatica,

GitHub:

- Gauzilla Pro
- 3D Gaussian Splatting for Real-Time Radiance Field Rendering, Inria
- 3D Gaussian Ray Tracing (3DGRT) and 3D Gaussian Unscented Transform (3DGUT), Nvidia (GS w/ 360 video)
- NerfStudio

Resources

Scanning:

- Scanning for Photogrammetry, Unreal Engine
- Tips for taking pictures for good photogrammetry, Autodesk

Applications:

- Scanning for Revolutionizing Construction Visualizations and Analyses with GeoAI, Radiance Fields, and Gaussian Splatting, Unreal Engine

Misc:

- Scanning for Triangle Splatting for Real-Time Radiance Field Rendering

YouTube:

- Olli Huttunen, Pixel Reconstruct,

Gallery

Plumaria, Victory Column, Polar Bear, Arrival Space, Story Splat,

Gaussian Splatting Part 2:
From Pixels to Presence

- Edit and refine GS Models for clean, polished results
- Explore **4D Gaussian Splatting** for dynamic scenes
- Workflows for **interior virtual tours** and walkthroughs
- Hands-on: Windows setup, GitHub installs, real community tools
- See how vendors & creatives are using splats for real-world XR applications