SplatDiet🥗:
Optimizing Gaussians for Efficient Navigation

2025. 11. 12

CS580 : Computer Graphics
Team #3 Team Project

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KAIST

Introduction

Problem Definition : Navigation in GSplat Map

1. Converting visual information into metrically consistent 3D geometry

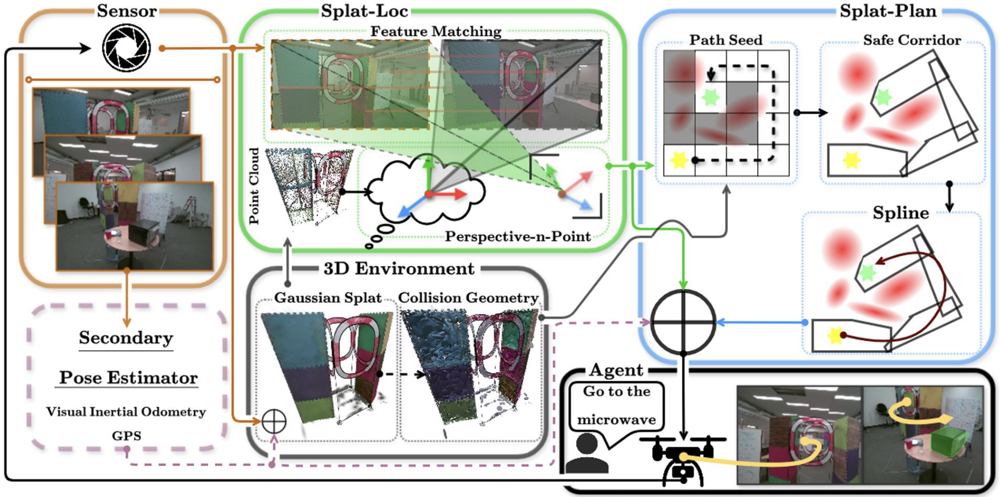
2. **Optimization for real-time onboard inference with limited compute**

- **Goal :** To reduce the computational overhead for real-time robot navigation **by pruning and merging redundant Gaussians** while preserving collision-path planning
  - Better capture collision geometry while reducing computational overhead
- **Key quality criteria**
  - Collision detection accuracy
  - Computational efficiency
  - Planning performance
- **Core challenges**
  - Collision-aware clustering
  - Voxel grid conversion bottleneck

Related Work

Baseline

- **SplatNav** : Safe Real-Time Robot Navigation in Gaussian Splatting Maps
  - 2025 T-RO
  - A navigation pipeline in GSplat maps using only an RGB Camera
- Splat-loc
  - Estimate the robot’s 6-DoF pose from a single RGB image
- Splat-Plan
  - Generate a safe curve trajectory



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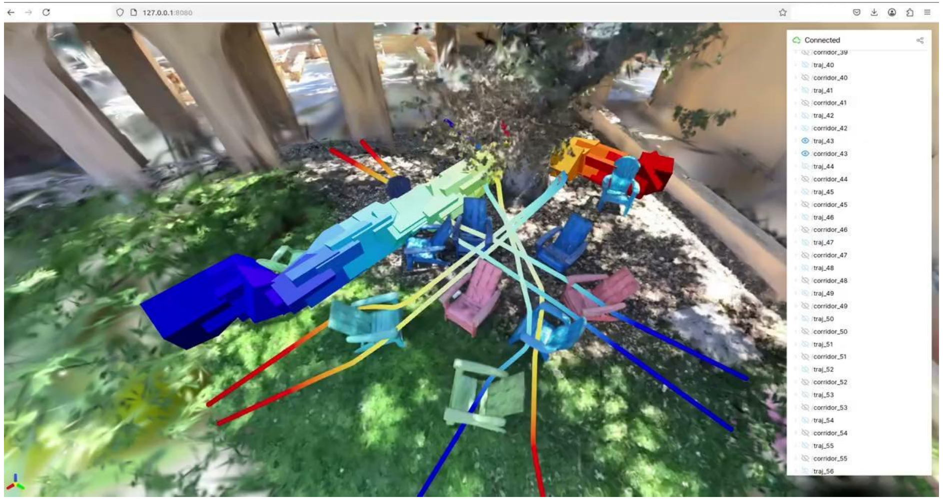
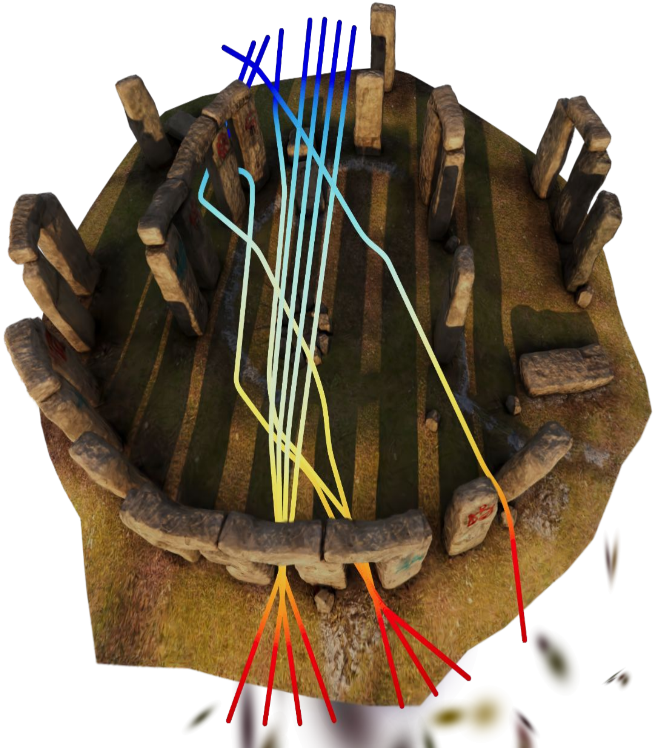
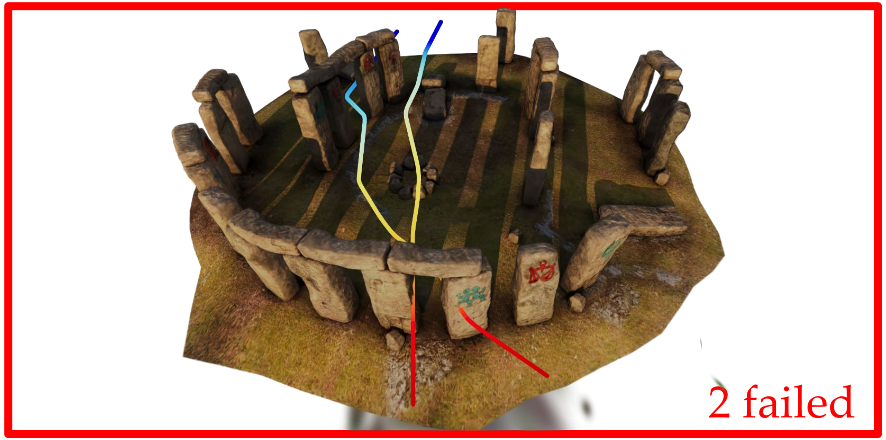
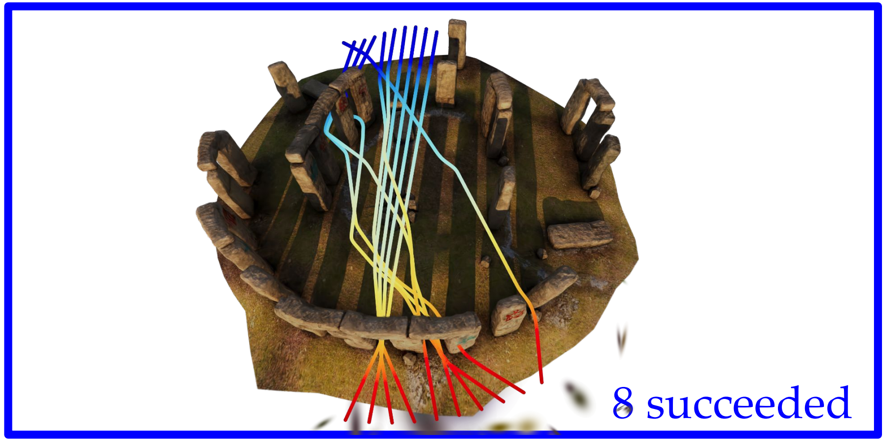


GSplat-Nav : Path planning

Scene : stonehenge

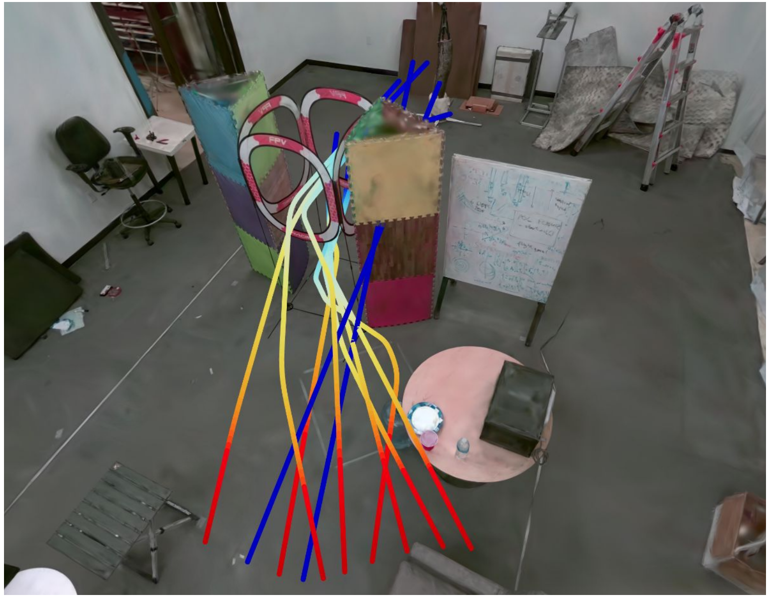


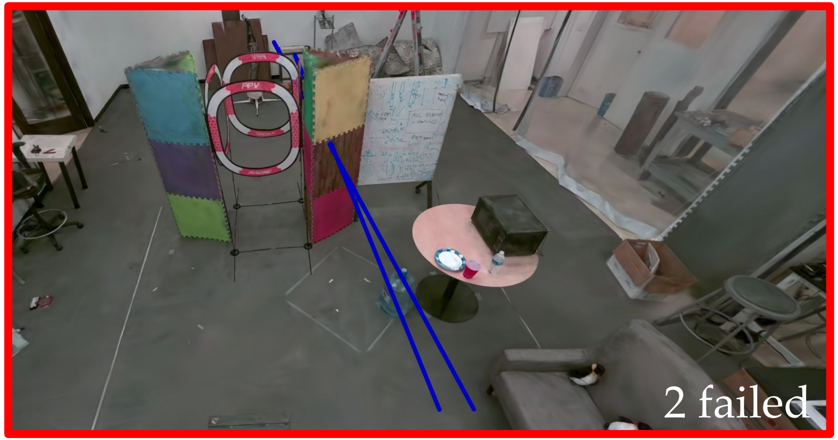




GSplat-Nav : Path planning

Scene : flight





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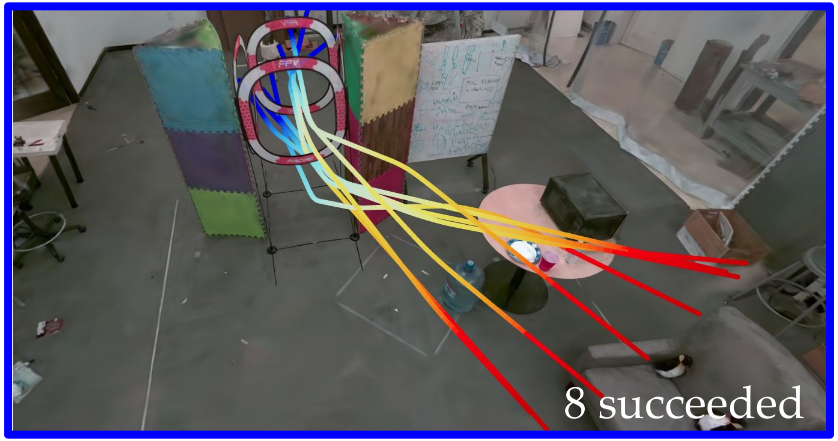

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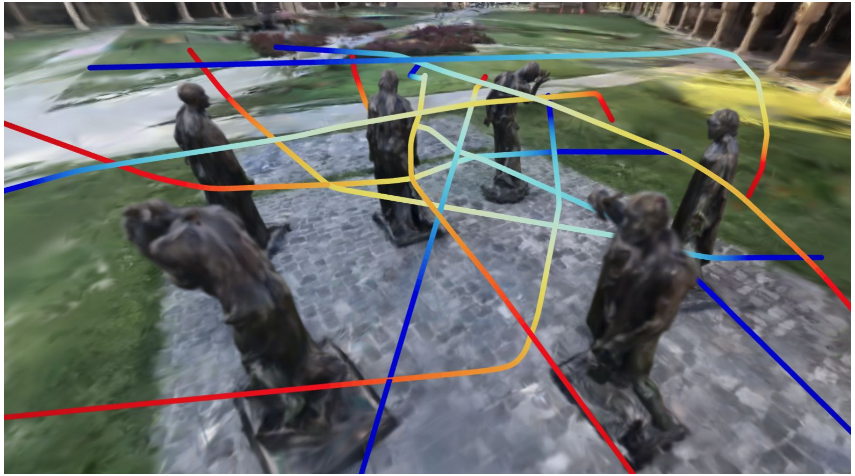
GSplat-Nav : Path planning

Scene : statues



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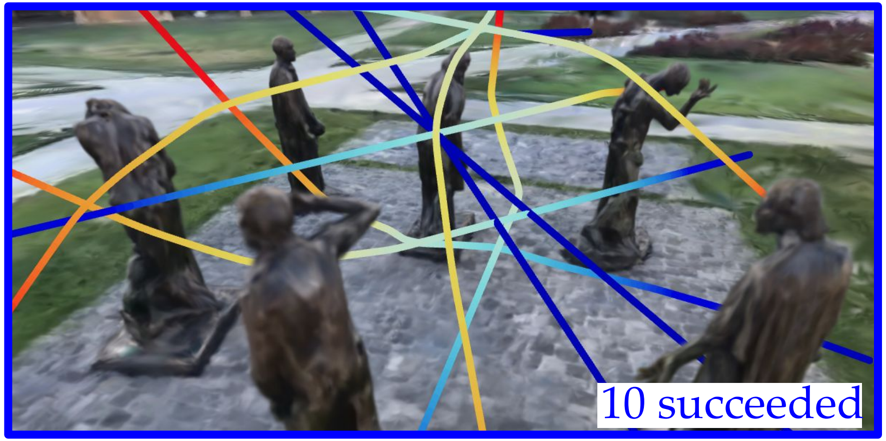

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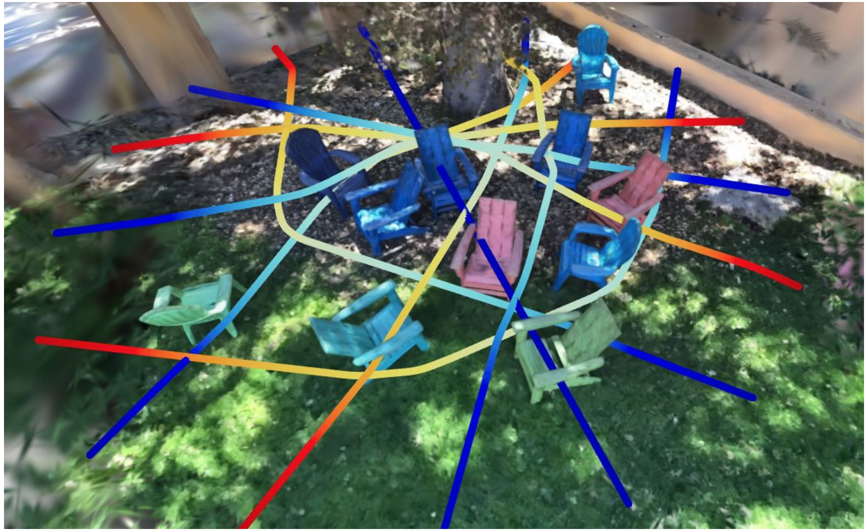
GSplat-Nav : Path planning

Scene : old union2



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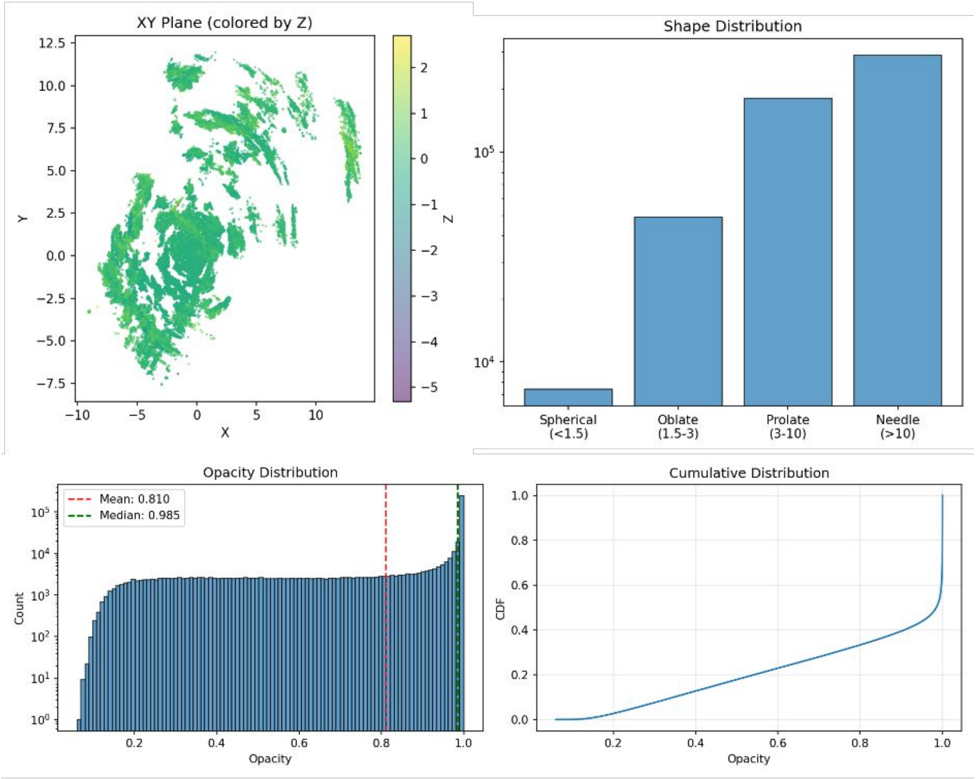
GSplat Map

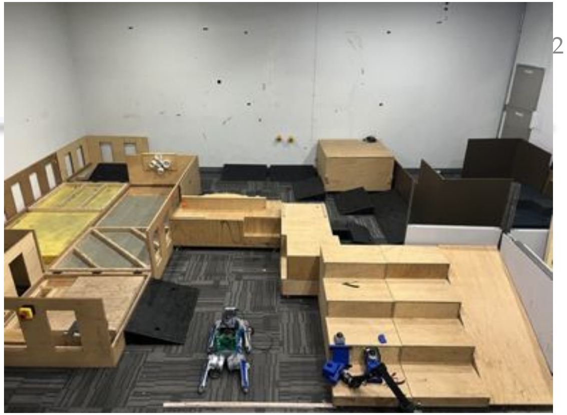
- Gaussian Analysis
  - Total num. : 525,734
  - Bimodal distribution
    - Mostly opaque
  - 76% are smaller than 1cm
  - 55% are needle-like shape

Occupied Cells	23,663 (0.67% of total space)
Average Density	22.2 gaussians per 10cm cell
Peak Density	6,673 gaussians
Mean Opacity	0.810
Median Opacity	0.985
Transparent (<0.1)	0.03
Opaque(>0.9)	60.5 %

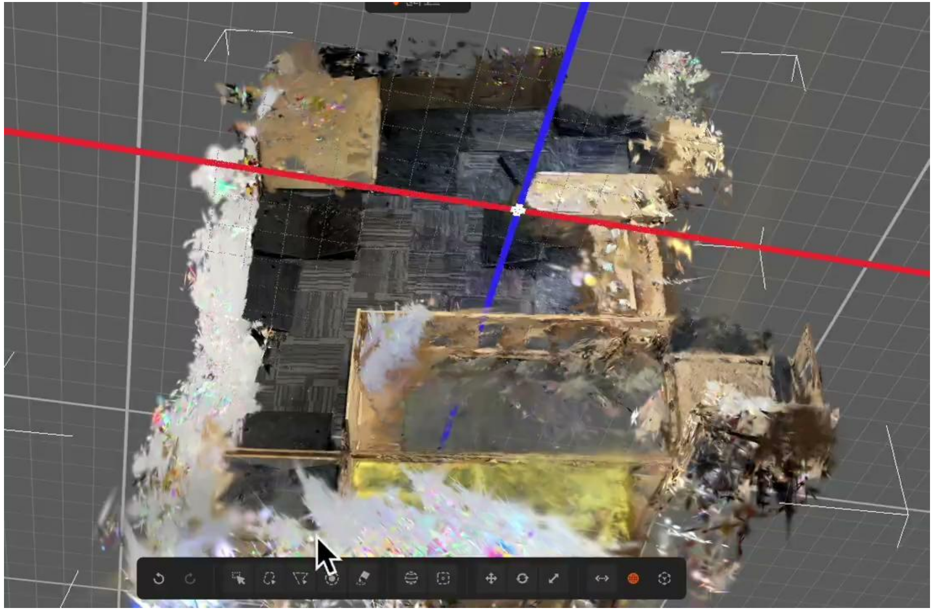


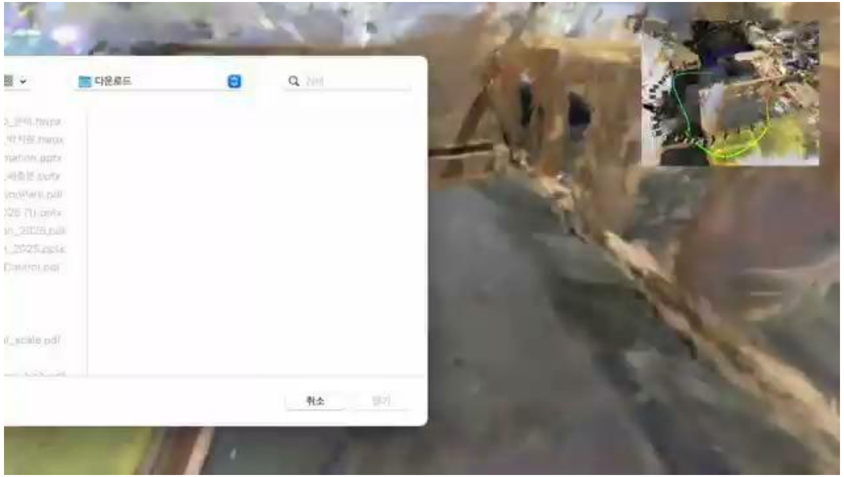
Limitations

What it looks like in real 👉



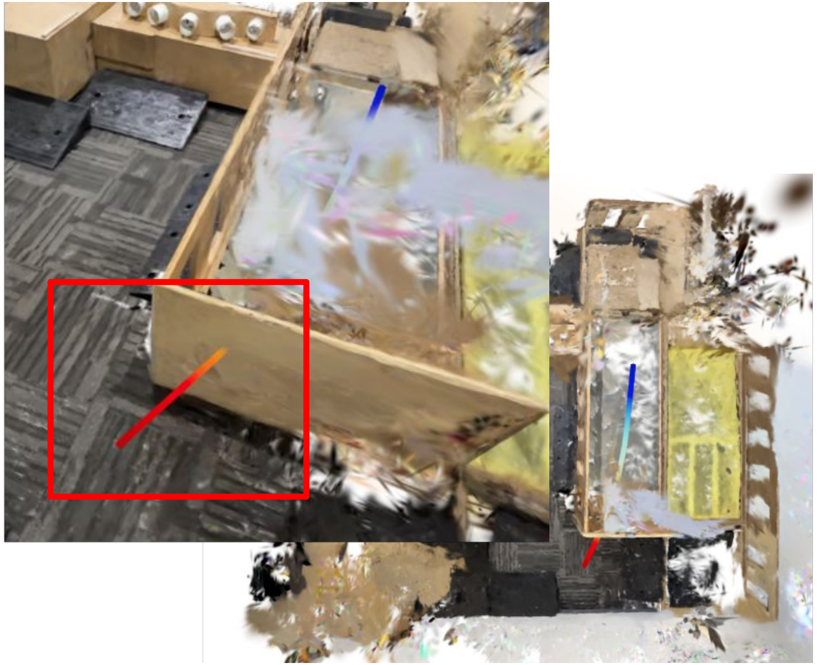
- Deploy on our own map





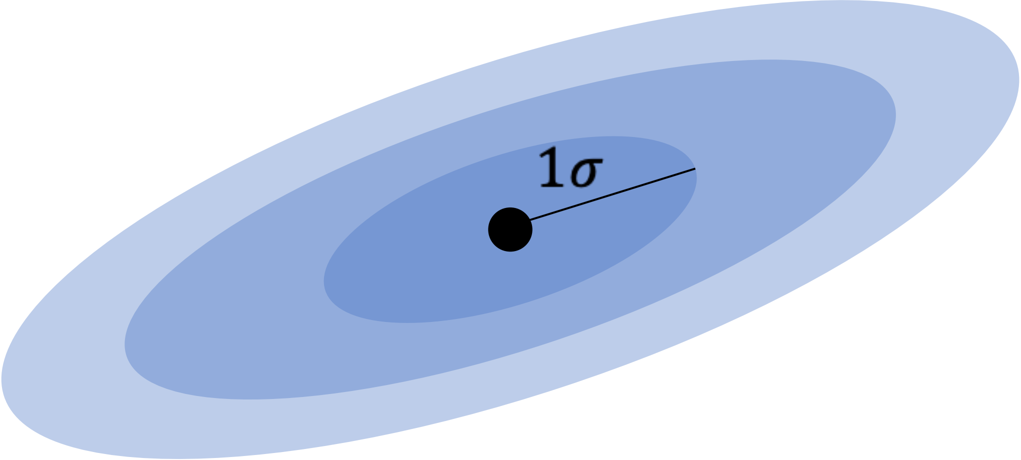
Limitations

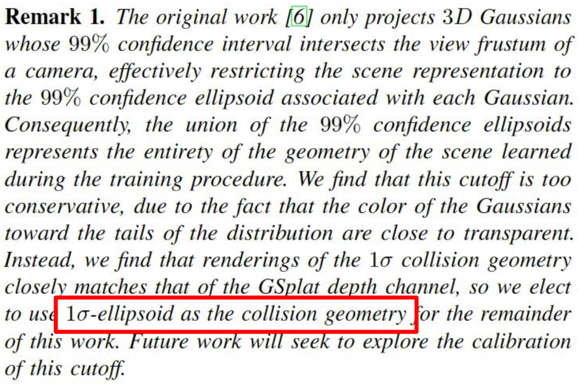
- Sparse map reconstruction led to incomplete collision geometry
- Collision checking failures due to gaps in the Gaussian representation
- Total num. Of Gaussians : 5,345,920 -> **OOM**



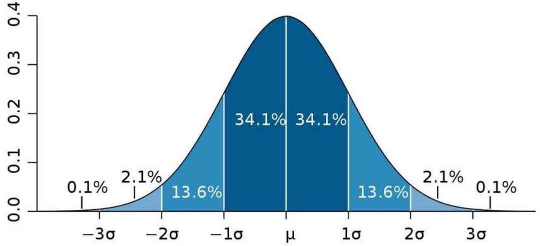
Limitations

- SplatNav adopted the 1σ ellipsoid as the collision geometry





Remark 1. *The original work [6] only projects 3D Gaussians whose 99% confidence interval intersects the view frustum of a camera, effectively restricting the scene representation to the 99% confidence ellipsoid associated with each Gaussian. Consequently, the union of the 99% confidence ellipsoids represents the entirety of the geometry of the scene learned during the training procedure. We find that this cutoff is too conservative, due to the fact that the color of the Gaussians toward the tails of the distribution are close to transparent. Instead, we find that renderings of the 1σ collision geometry closely matches that of the GSplat depth channel, so we elect to use 1σ-ellipsoid as the collision geometry for the remainder of this work. Future work will seek to explore the calibration of this cutoff.*



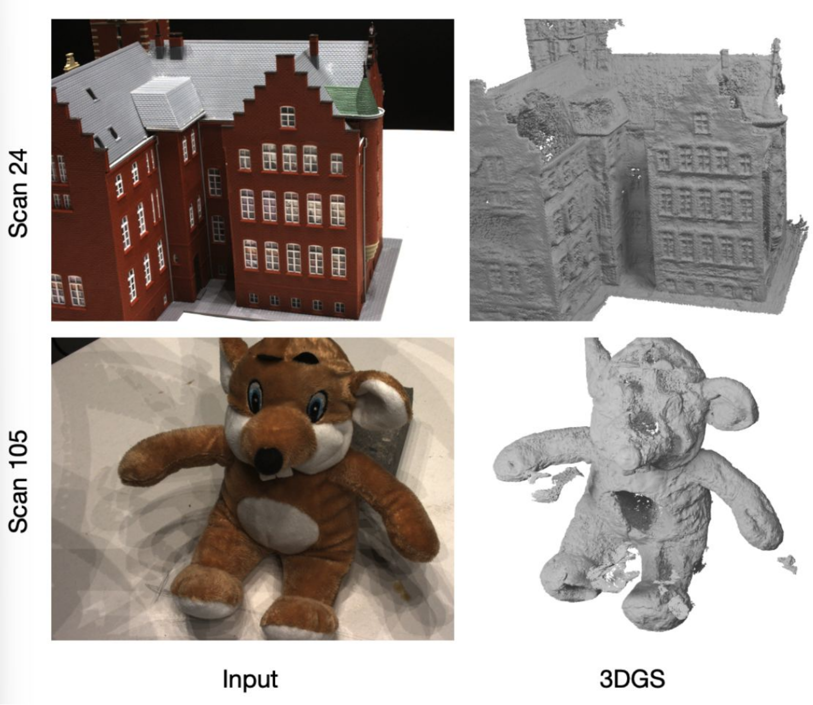
Why Move Beyond GSplat-Nav?

#1) Efficiency

-

The Core Problem with 3DGS for Geometry

- Fuzzy Surfaces



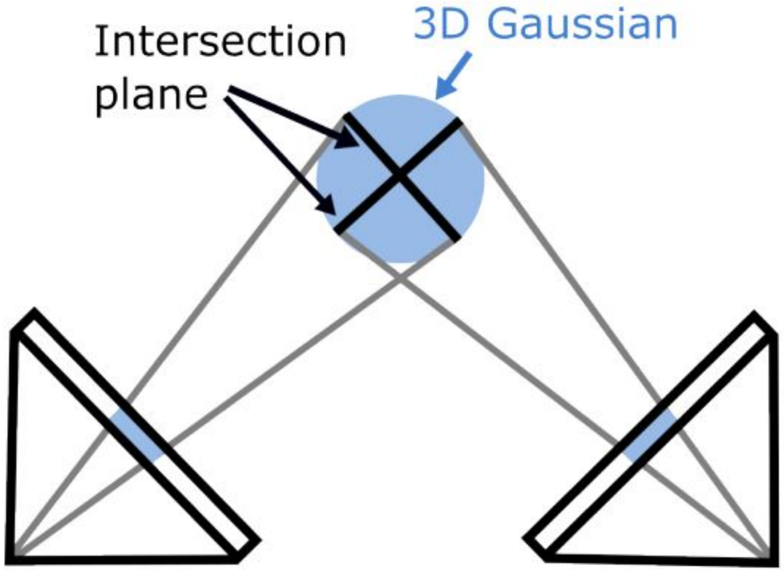
Binbin Huang, Zehao Yu, Anpei Chen, Andreas Geiger, Shenghua Gao. “2DGS: 2D Gaussian Splatting for Geometrically Accurate Radiance Fields”. SIGGRAPH, 2024.

The Core Problem with 3DGS for Geometry

- False Obstacles

The Core Problem with 3DGS for Geometry

- Inconsistent views



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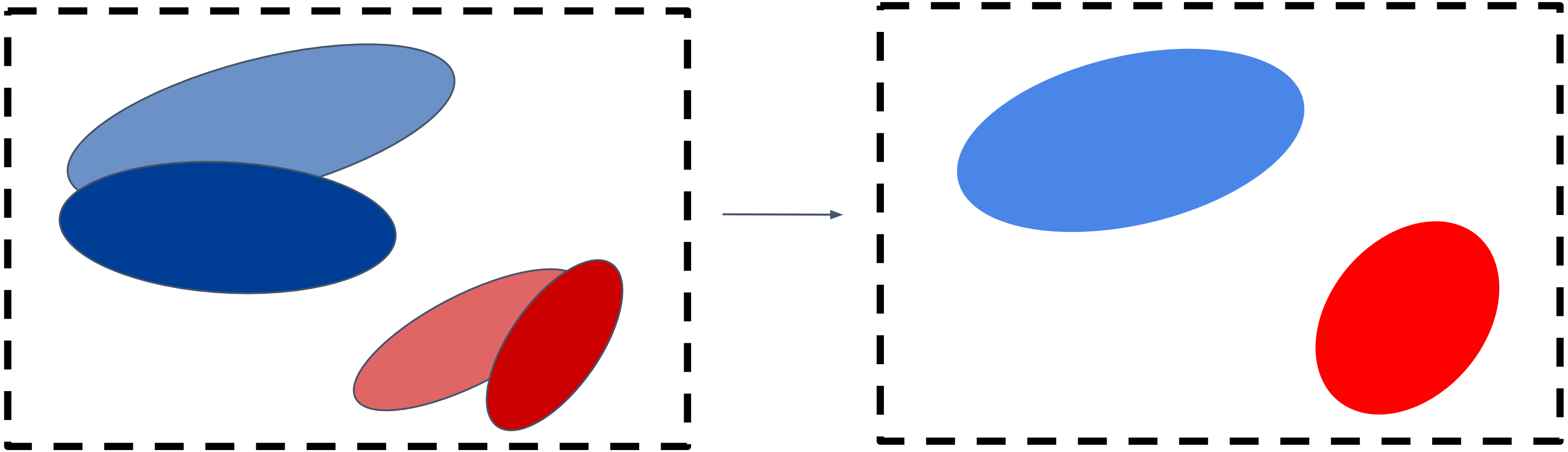
Proposal

Trial #1

1) Remove low-opacity Gaussians

2) Merge nearby Gaussians into Super Splats

- Simple radius-based connected-components merge where the merge threshold is proportional to the sizes of the two Gaussians.



Trial #1

Scene : stonehenge (116446 gaussians)

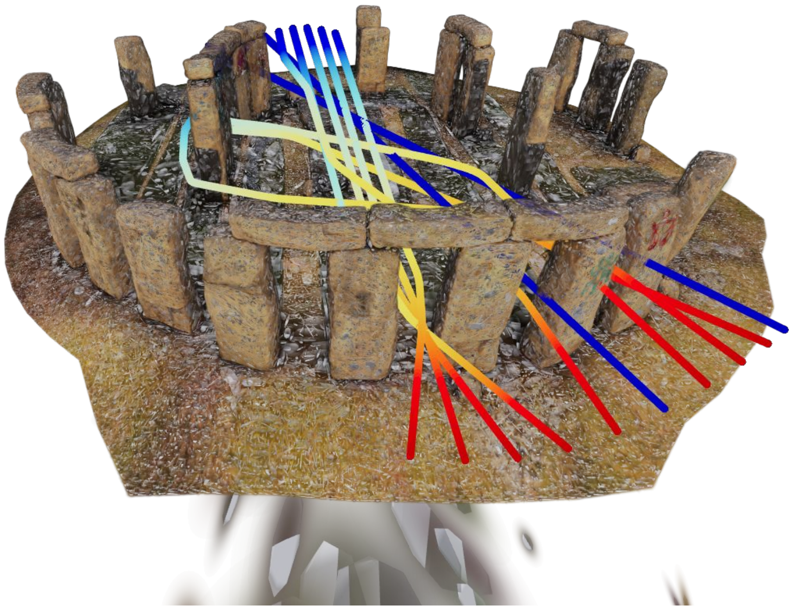
After
Gaussian diet

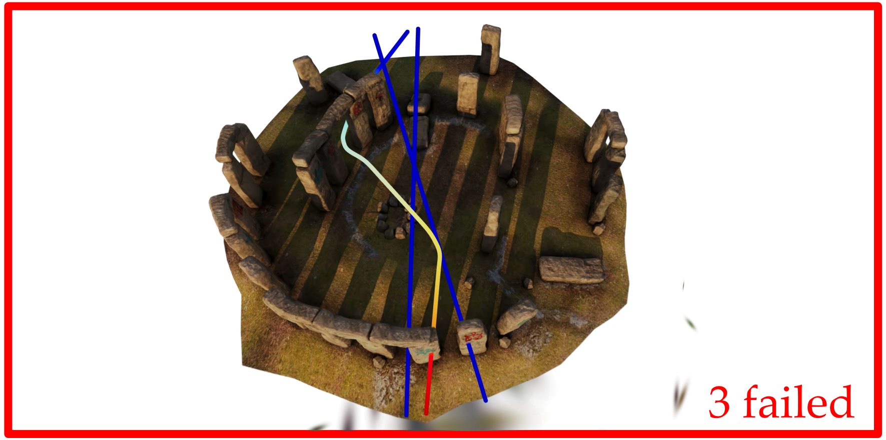
Removed 88380 Gaussians

Remaining 28066 Gaussians

Trial #1 : Result of trajectory planning

Original SplatNav





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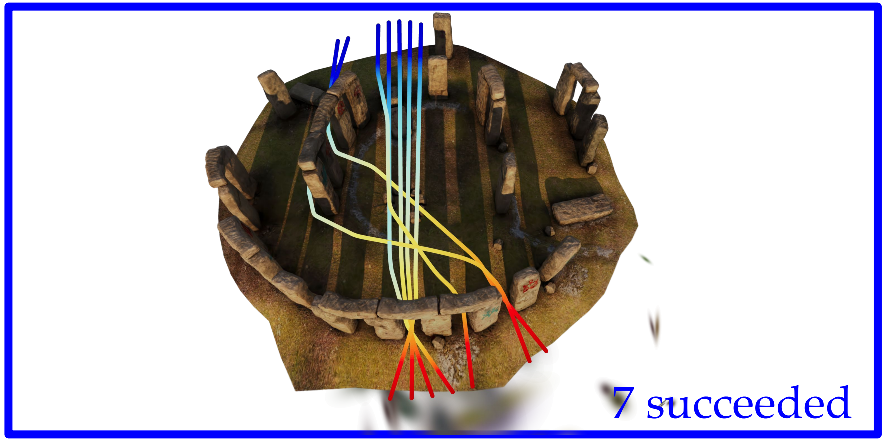

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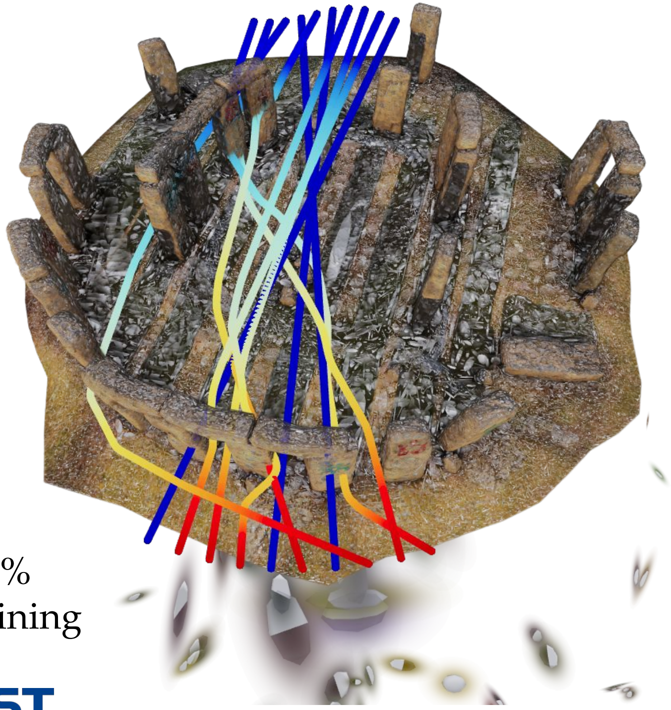
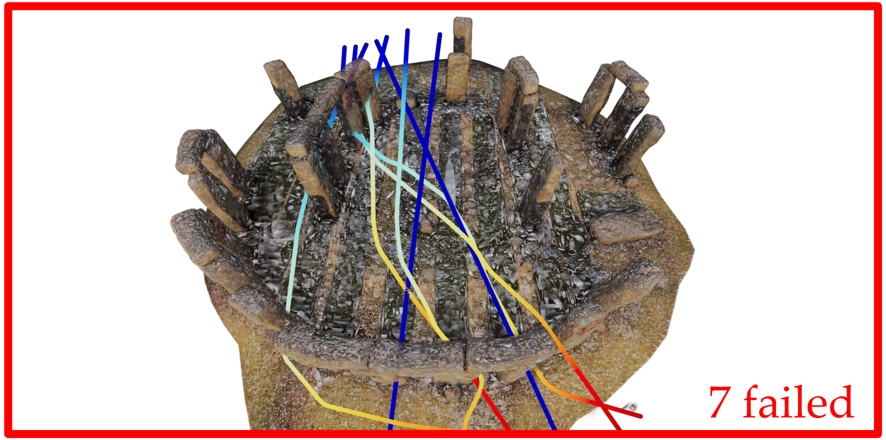
Trial #1 : Result of trajectory planning

Dieted (28066 gaussians)



24%
remaining



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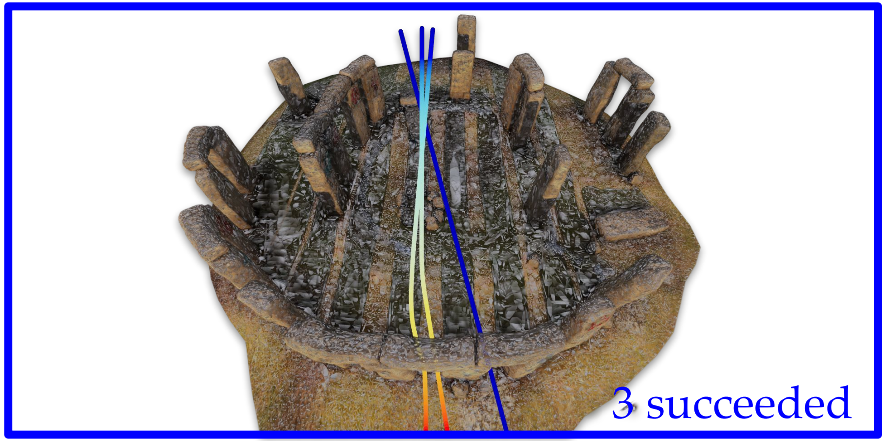

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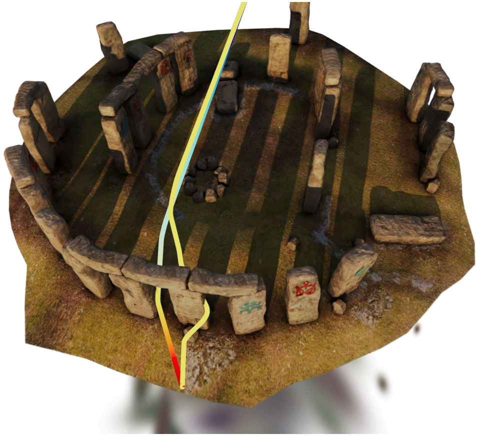
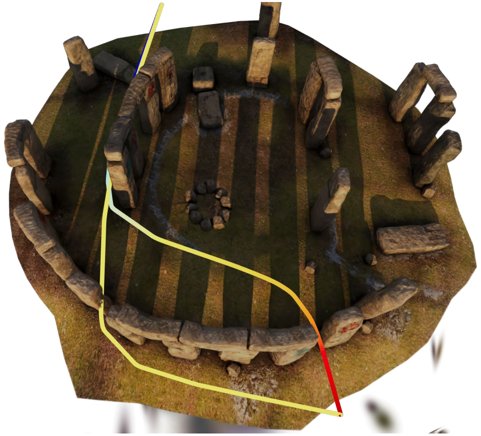
Trial #1 : Result Analysis

- The planner creates paths that “clip” or “brush” the edges of obstacles.





- Problem in merging logic! It **shrinks geometry**.

  => Stricter threshold for grouping / conservative merging strategy needed!

Trial #2

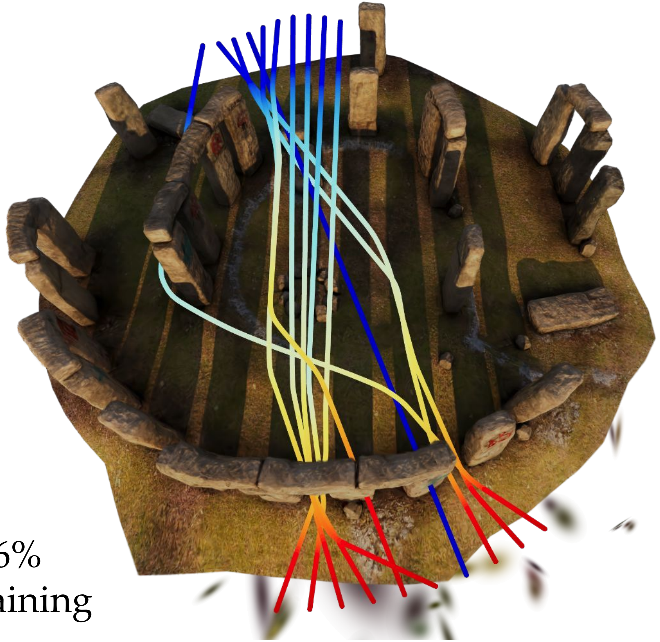
1) Remove low-opacity from GSplat map

2) Group gaussians based on their distance

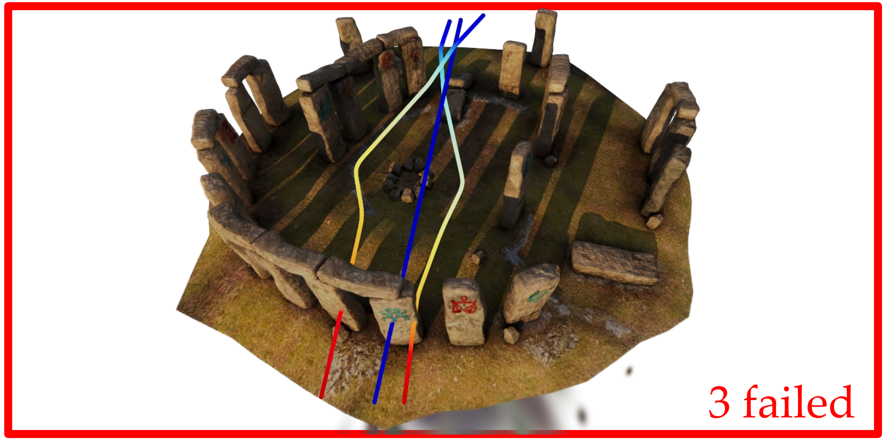
3) Make a **new merged Gaussian that safely encloses its members.**

Trial #2 : Result of trajectory planning

Dieted (76781 gaussians)
Merge factor = 0.5



66%
remaining



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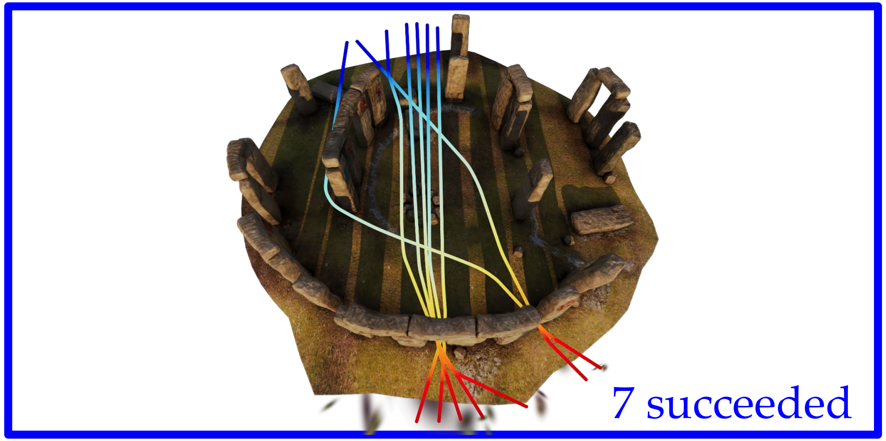

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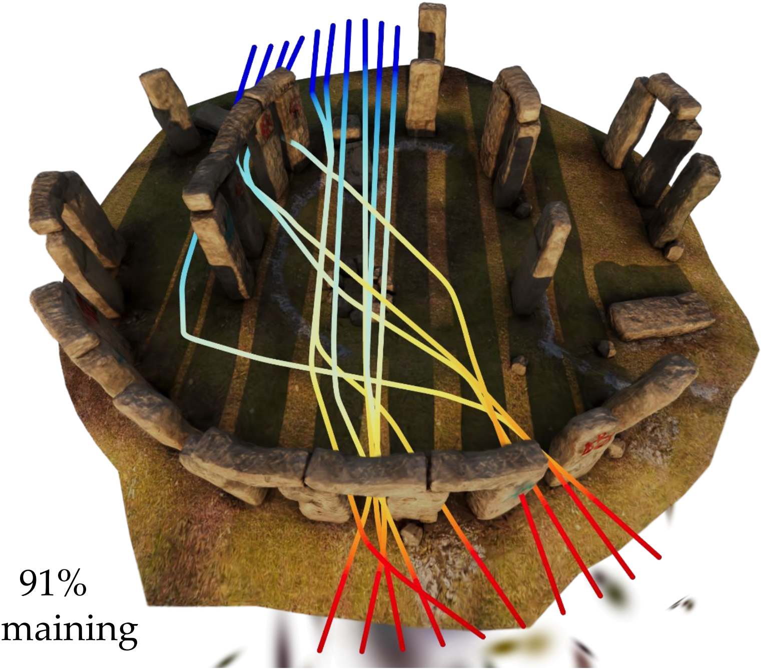
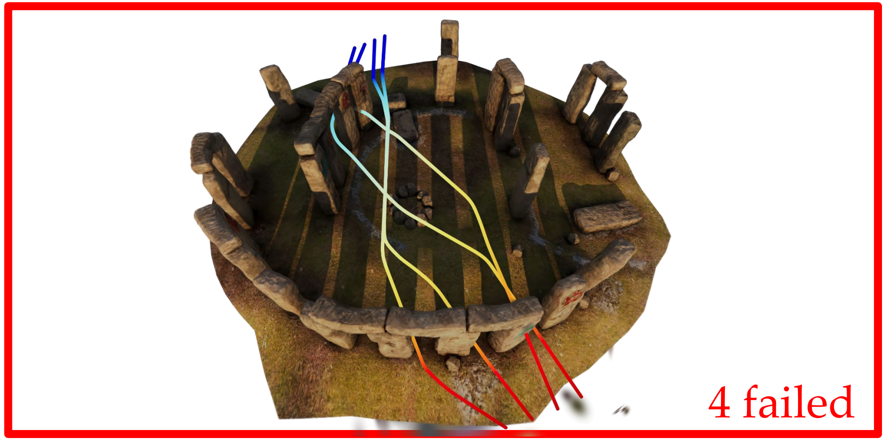
Trial #2 : Result of trajectory planning

Dieted (106050 gaussians)
Merge factor = 0.25



91%
remaining



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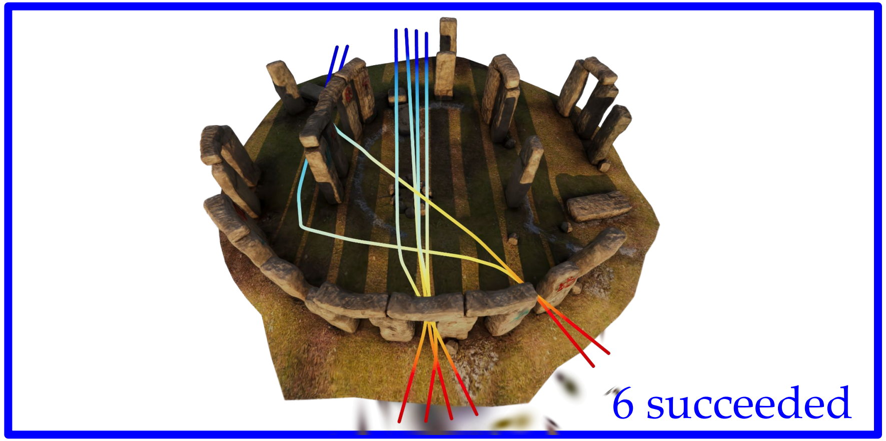

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Trial #2 : Result Analysis

- Wrong merging strategy was leading to misperformance.

- Is merging helping the planner?

Plan

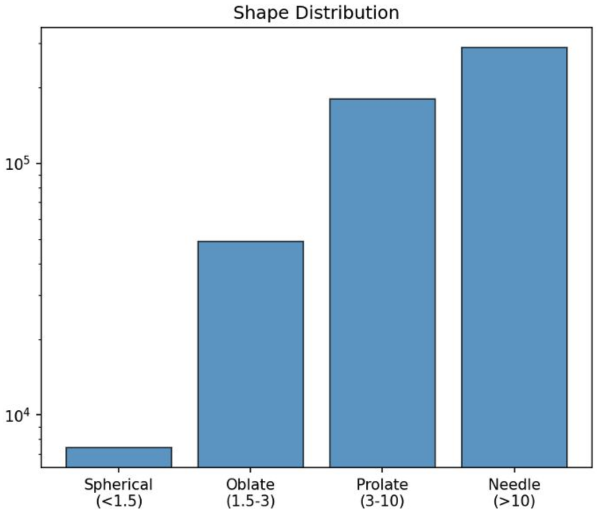
- Optimization
  - Quantitative evaluation of SplatDiet's effectiveness
    - Measure computational efficiency improvements
    - Evaluate planning performance with reduced Gaussians
    - Assess collision detection accuracy after merging
- Geometry
  - Improving collision representation
    - Refine the 1σ ellipsoid collision boundary
    - Explore integration with 2DGS maps for better surface representation

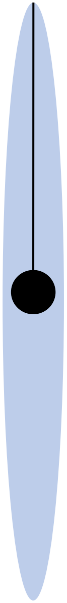
1. Optimization : Effective Merging

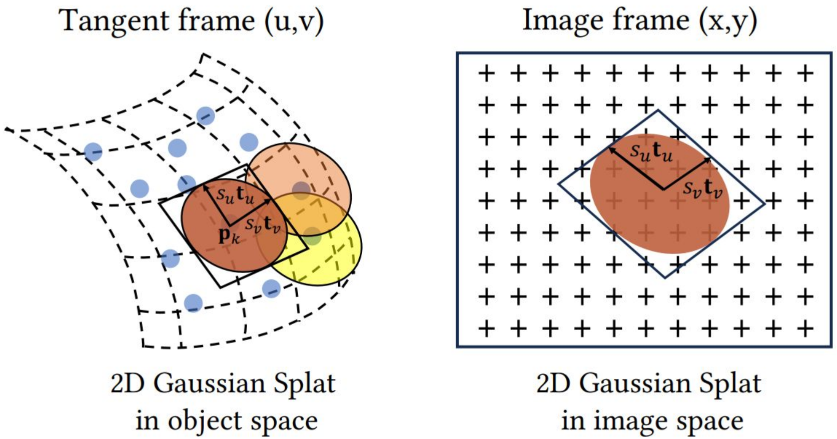
2. Geometry : Decision of collision boundary (sigma)

Plan

- Implementation of 2DGS Map







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Q&A

Role

Jiwon Park

- Code implementaion
- Result Analysis & Comparison

Harin Kim

- Code Implementation
- Result Analysis & Comparison

Each of us implement different solution, and go with the one that yields better results