Sketch and Patch: Efficient 3D Gaussian Representation for Man-Made Scenes

MMVE'25, Stellenbosch

Yuang Shi, Simone Gasparini, Géraldine Morin, Chenggang Yang, Wei Tsang Ooi

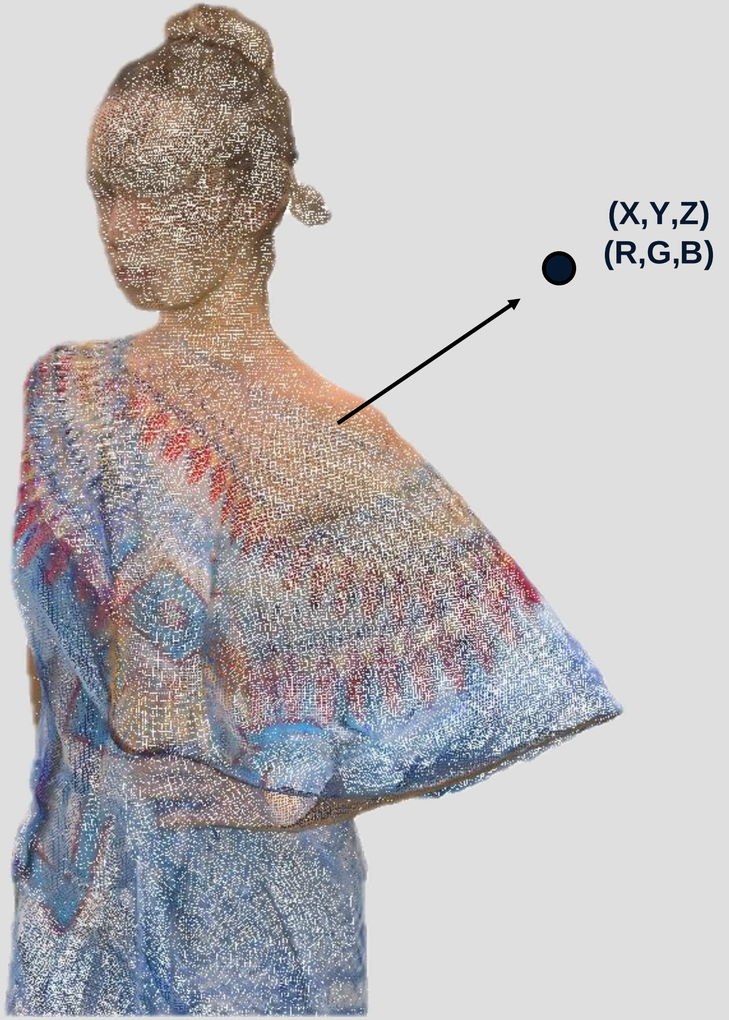
Sketch and Patch: Efficient 3D Gaussian Representation for Man-Made Scenes

MMVE'25, Stellenbosch

Yuang Shi, Simone Gasparini, Géraldine Morin, Chenggang Yang, Wei Tsang Ooi

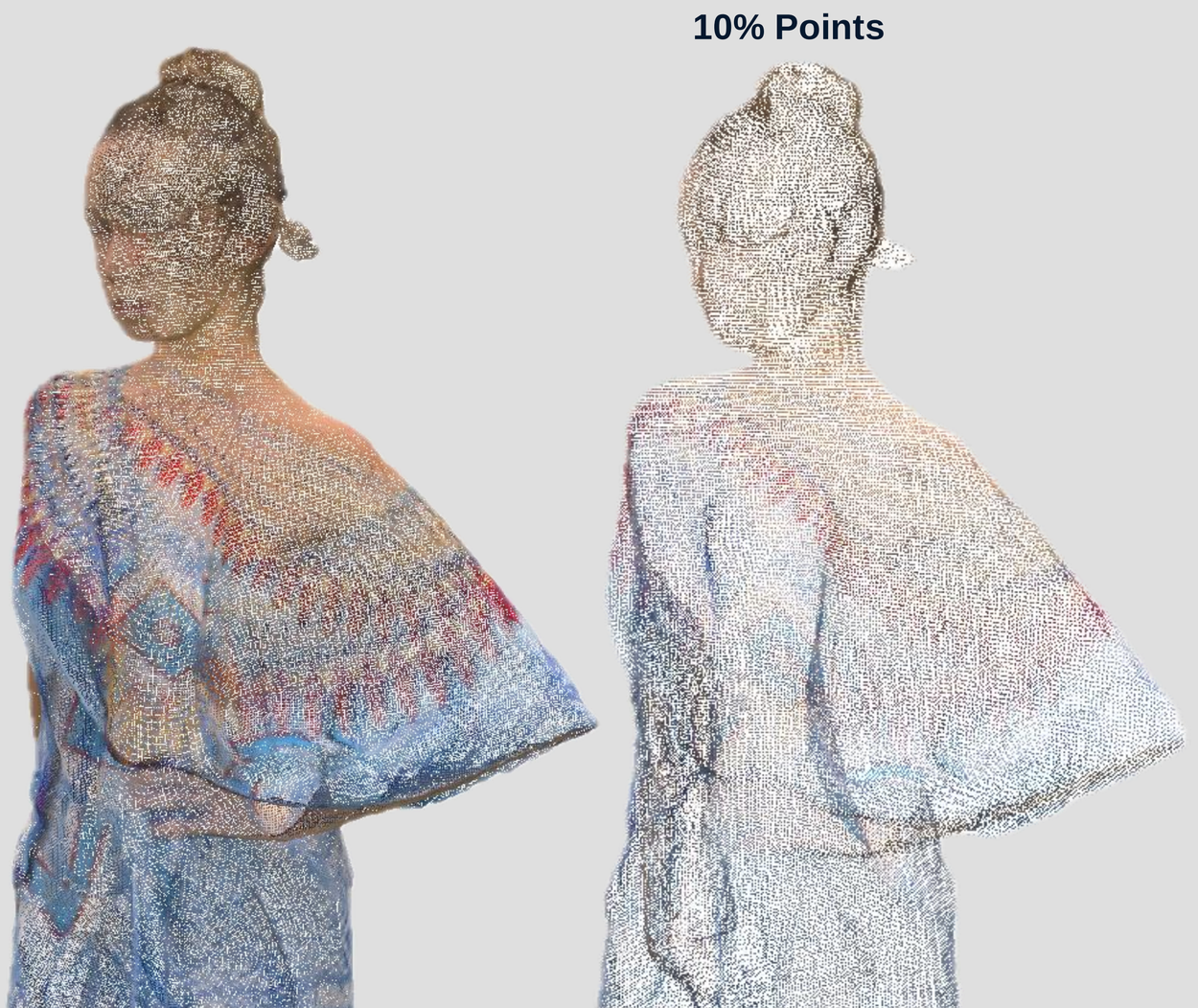
3D (Explicit) Representation

- **3D Point Cloud**
  - 3D points with geometry (X, Y, Z) and attribute (R, G, B) information



Point Cloud — Advantage

- **3D Point Cloud**
  - Unstructured 3D points can be easily processed, e.g., down-sample

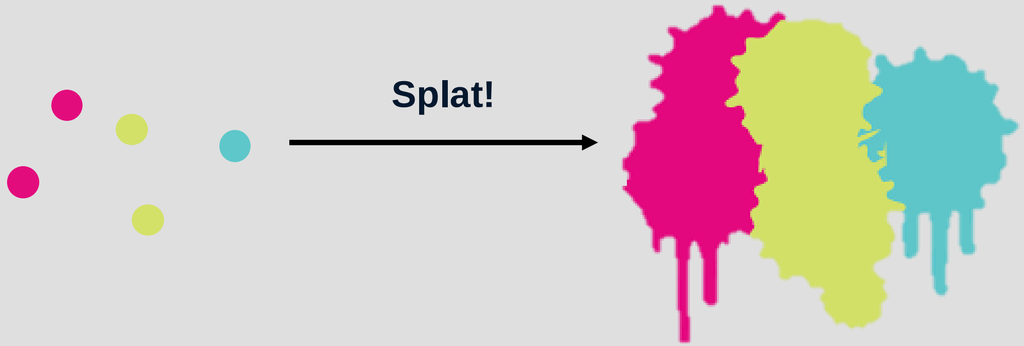


Point Cloud — Limitation

- **3D Point Cloud**
  - Points are sparse and irregular, which cause artifacts, e.g., holes

Point Cloud Improvement

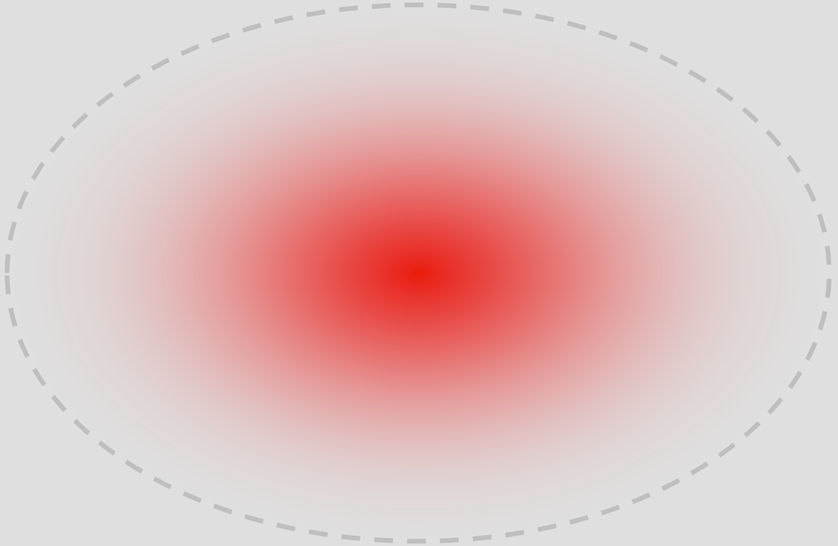
- **Point → Splat**
  - Extend the 3D point to other shapes.
    - For example: Circular, Elliptic Discs, or Ellipsoids



Gaussian Splat (GS)

- **Point → Gaussian Splat**
  - Extend the 3D point to Elliptical Gaussian
  - **Only for rendering (2D)**

A Gaussian Splat

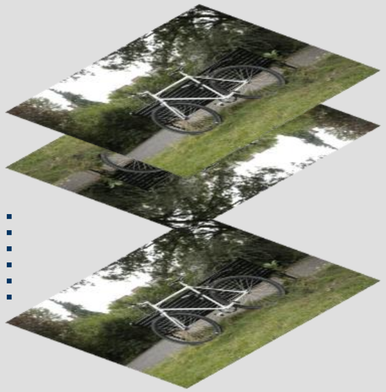


[1] Zwicker, Matthias, et al. "Surface Splatting."
Proceedings of the 28th annual conference on Computer graphics and interactive techniques. 2001.

3D Reconstruction with 3D GS

- **Reconstruct the 3D Worlds with 3D GS (after 20 years)**

2D Images



3DGS Algorithm

3DGS Model

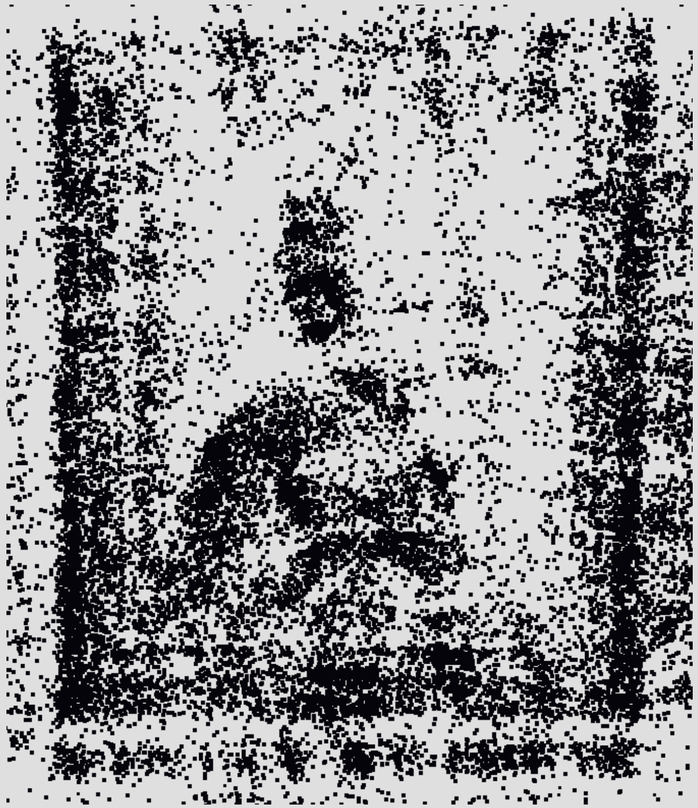
[1] Kerbl, Bernhard, et al. "3D Gaussian Splatting for Real-time Radiance Field Rendering." ACM SIGGRAPH 2023.
Best Paper Awards.

3D GS —— Example

3DGS Rendering

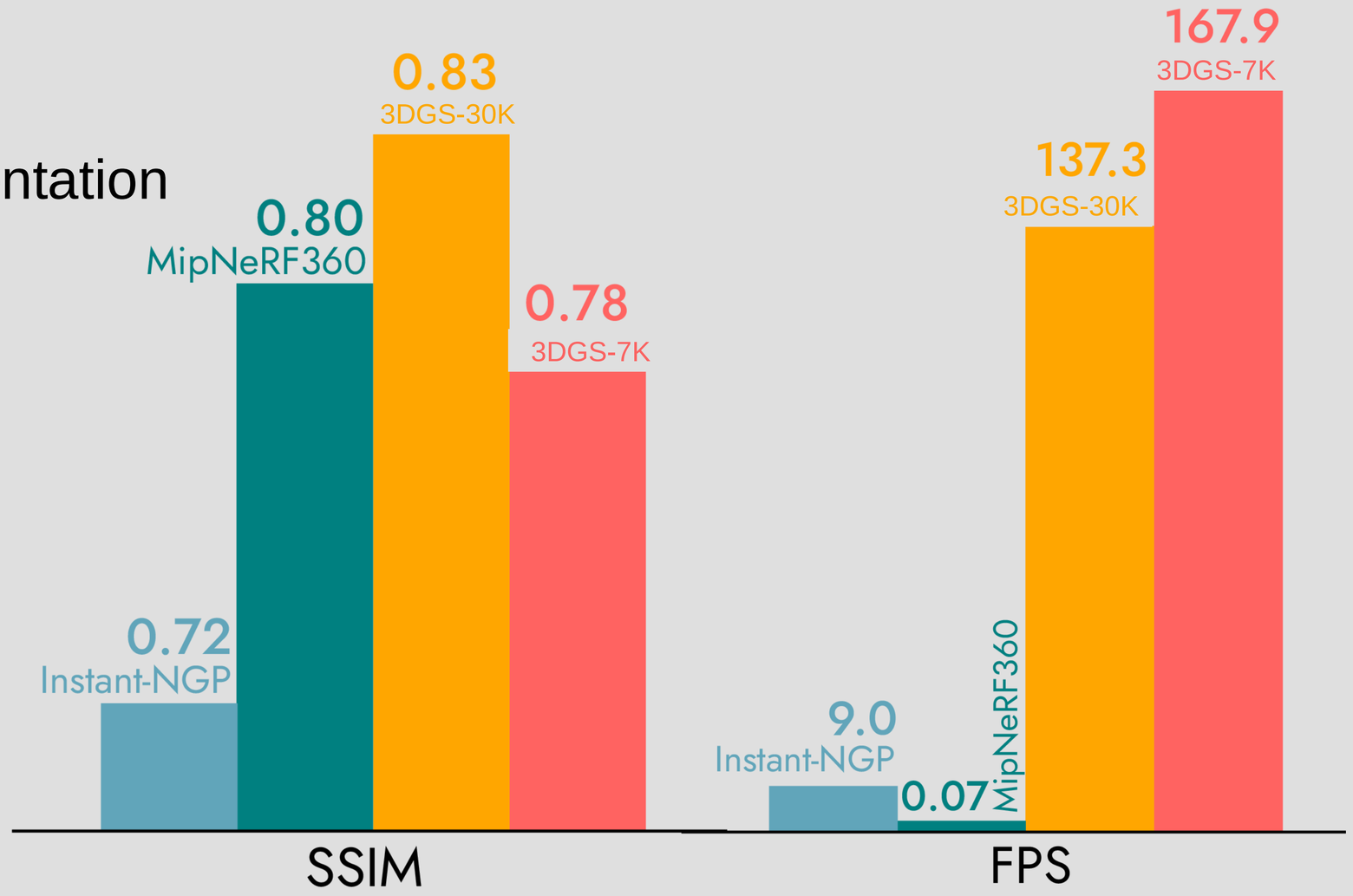
Ellipsoids of the 3DGS

Center of the 3DGS



3DGS — Advantage

- As a learning-based representation
  - **Photorealistic Quality**
  - **Super Fast Rendering**
  - **Explicit Representation**



3DGS — Limitation

- **3DGS Model Size**
  - This 3D scene requires
    - **6,000,000+** Gaussian splats
    - **1.5** GB

3DGS Streaming

Virtual Environment

streams

interaction

Internet

streams

interaction

Server

Users

Extremely Heavy!!

?

Scalable Coding?
Tiling?

Advertisements to Our Works

- **LapisGS: Layered Progressive 3DGS Representation (3DV'25)**

Try LapisGS and LTS!

LapisGS: Layered Progressive 3D Gaussian Splatting for Adaptive Streaming

Yuang Shi[1,3] Géraldine Morin[2,3] Simone Gasparini[2,3] Wei Tsang Ooi[1,3]

[1]National University of Singapore [2]IRIT - University of Toulouse [3]IPAL, IRL2955, Singapore
{yuangshi, ooiwt}@comp.nus.edu.sg {geraldine.morin, simone.gasparini}@toulouse-inp.fr

- **DASH 3DGS Streaming System based on LapisGS (MMSys'25, Wednesday)**

LTS: A DASH Streaming System for Dynamic Multi-Layer 3D Gaussian Splatting Scenes

Yuan-Chun Sun[1], Yuang Shi[2], Cheng-Tse Lee[1], Mufeng Zhu[3], Wei Tsang Ooi[2], Yao Liu[3], Chun-Ying Huang[4], and Cheng-Hsin Hsu[1]
[1]National Tsing Hua University, Taiwan
[2]National University of Singapore, Singapore
[3]Rutgers University, NJ, USA
[4]National Yang Ming Chiao Tung University, Taiwan

3DGS Streaming

Virtual Environment

streams

interaction

Internet

streams

interaction

Server

Users

Extremely Heavy!!

?

Compression!

Sketch and Patch: Efficient 3D Gaussian Representation for Man-Made Scenes

MMVE’25, Stellenbosch

Yuang Shi, Simone Gasparini, Géraldine Morin, Chenggang Yang, Wei Tsang Ooi

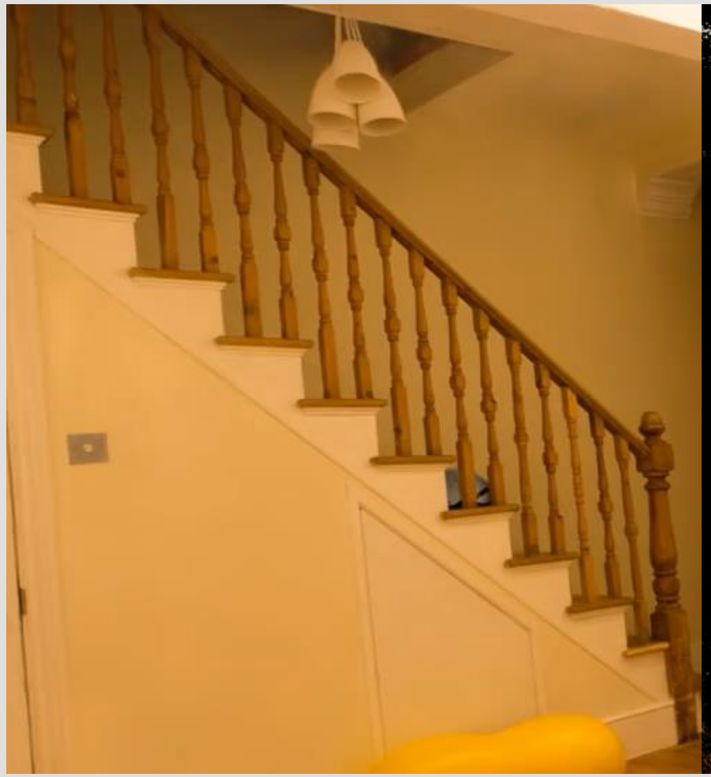
Sketch and Patch: Efficient 3D Gaussian Representation for Man-Made Scenes

MMVE'25, Stellenbosch

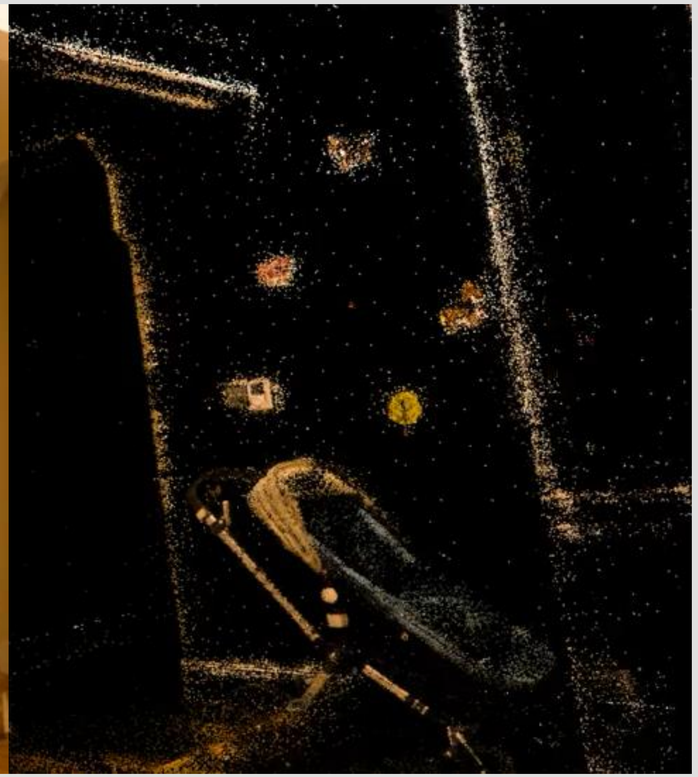
Yuang Shi, Simone Gasparini, Géraldine Morin, Chenggang Yang, Wei Tsang Ooi

Look into 3DGS Scene

- **Some splats cluster along structural boundary** **Why?**
  - Cover limited area, but occupy over 70% model size
- **Some splats are sparsely distributed over smooth area**
  - Cover broader area, but occupy below 30% model size



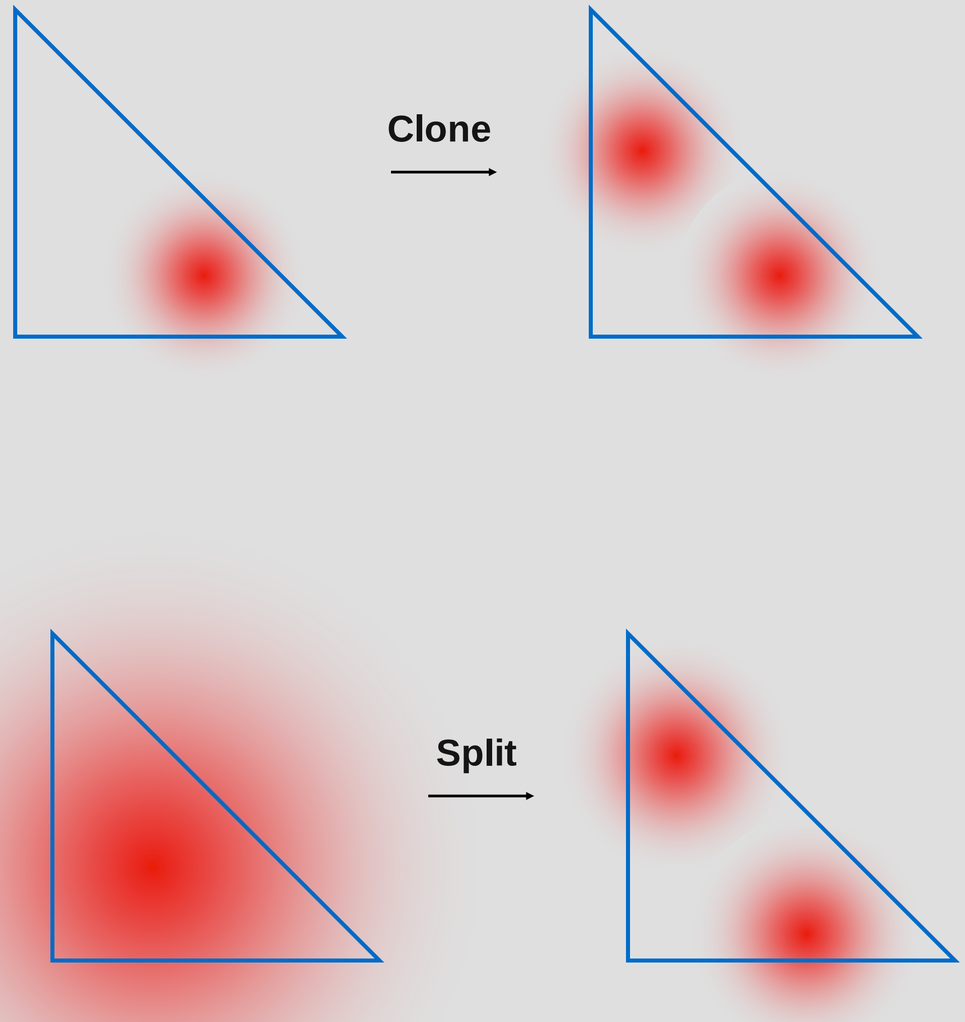
Rendered 3DGS



Center of Gaussian Splats

3DGS Densification

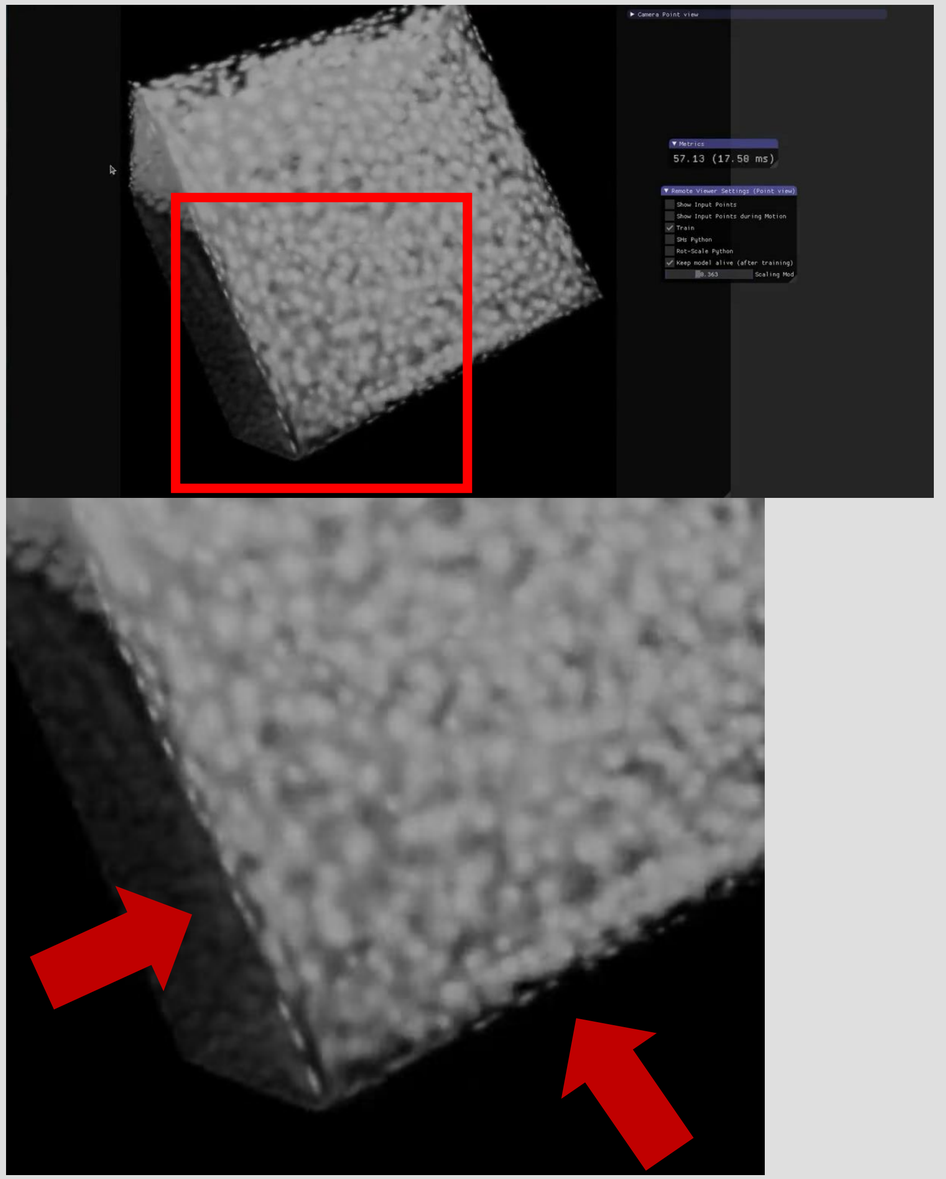
- **Densify the splats for fine details**
  - **If too small**: clone to fill the area
  - **If too big**: split to fit the area



Densification Demo

- **Tend to add much more splats into high-frequency area**
  - Especially for object boundaries, edges

Video of training



Densification during training

Look into 3DGS-based Scene

- **Can we try to utilize this feature?**

Rendered 3DGS **Center of Gaussian Splats**

Sketch and Patch:
Efficient 3D Gaussian Representation for Man-Made Scenes

MMVE’25, Stellenbosch

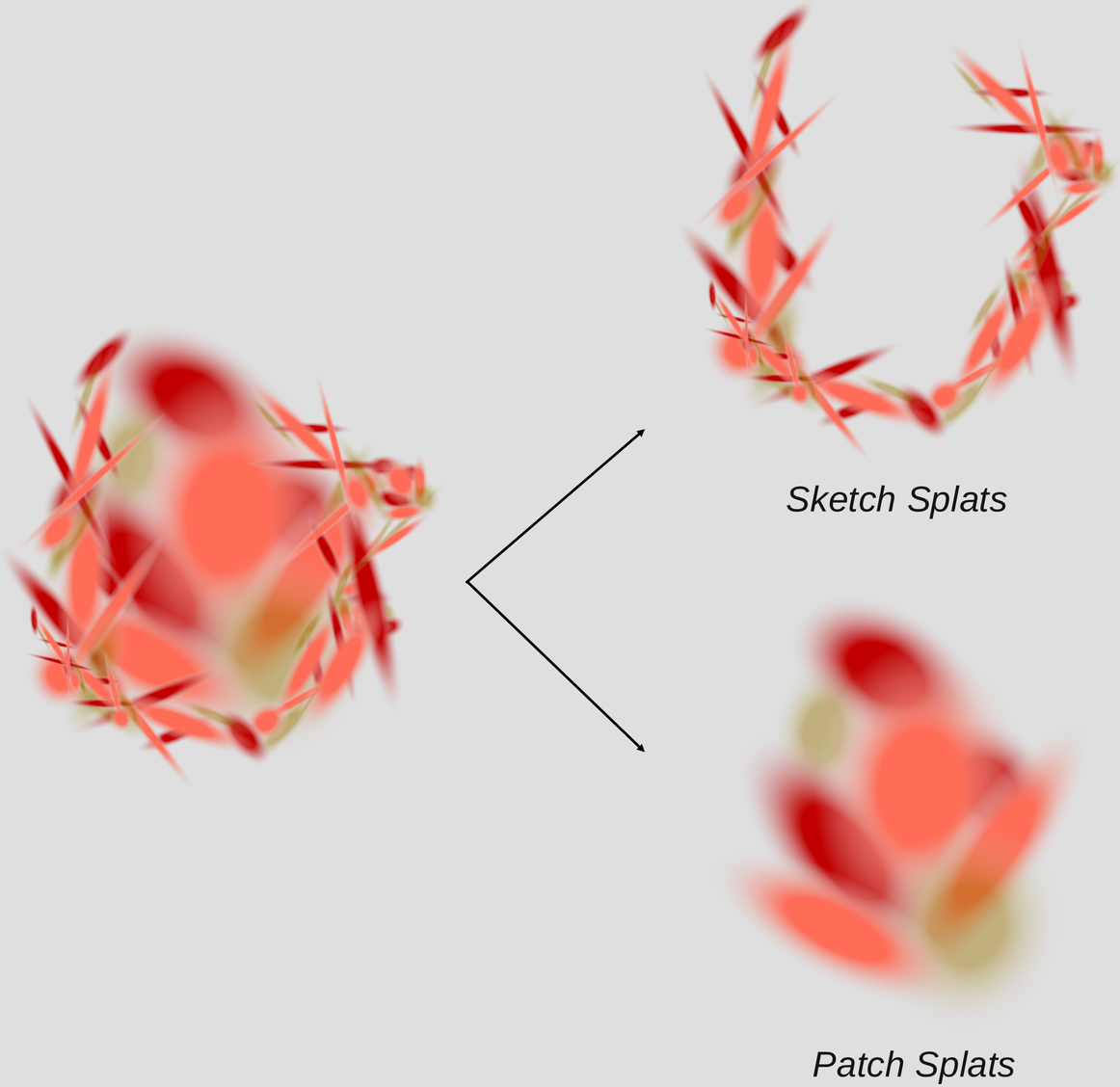
Yuang Shi, Simone Gasparini, Géraldine Morin, Chenggang Yang, Wei Tsang Ooi

Sketch & Patch

- **Draw a painting**
  - **Sketch** outlines
  - **Patch** the broader area
- **Similar to what we observed from 3DGS!**

Sketch & Patch

- **Categorize splats into**
  - **Sketch** Splats
    - Boundary-defining
    - Semantic scaffolding
  - **Patch** Splats
    - Smoother and broader regions

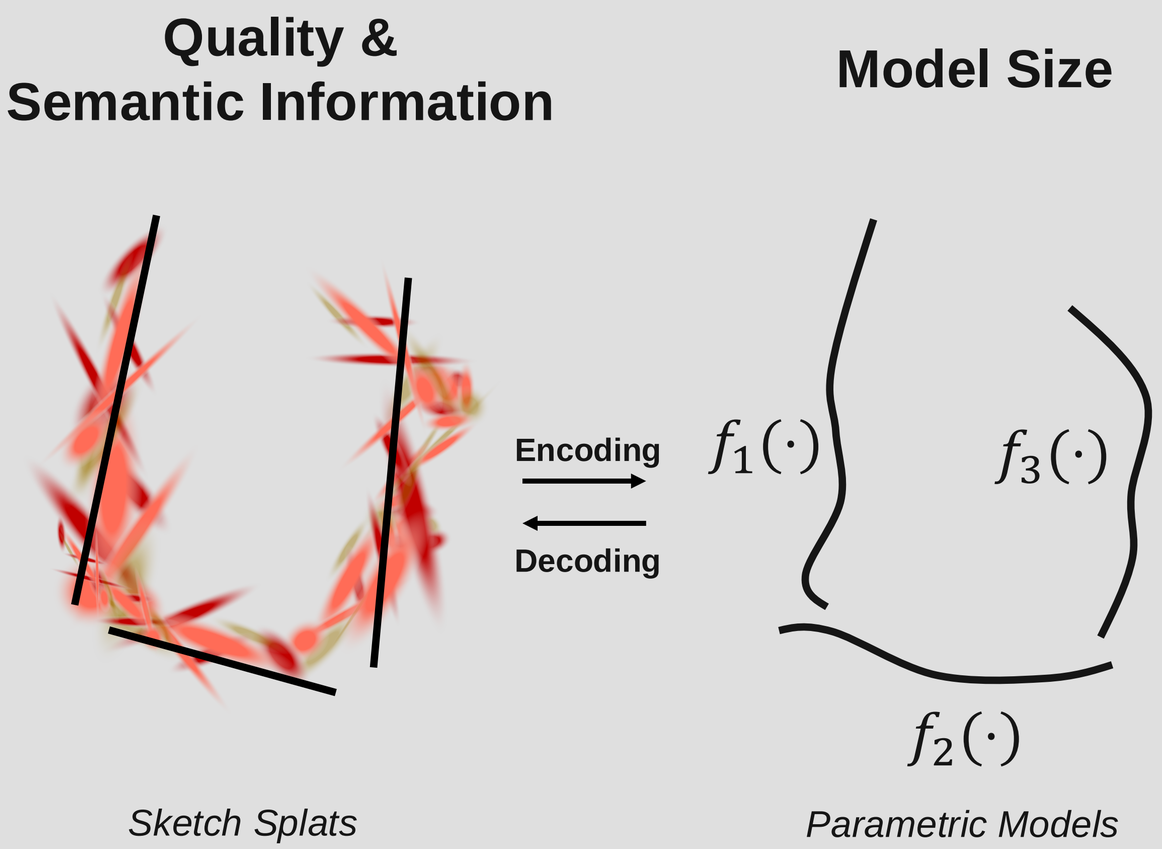


Sketch Splats

Patch Splats

Sketch

- **Sketch Splats**
  - Densely populated
  - Boundary-defining feature
- **Linear or Curvilinear**
- **Error-Tolerant**

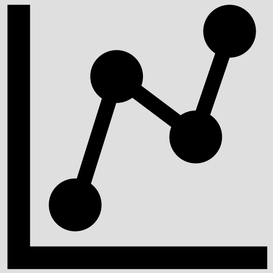


Sketch —— Example

Sketch Splats

379.9 MB

Encoding

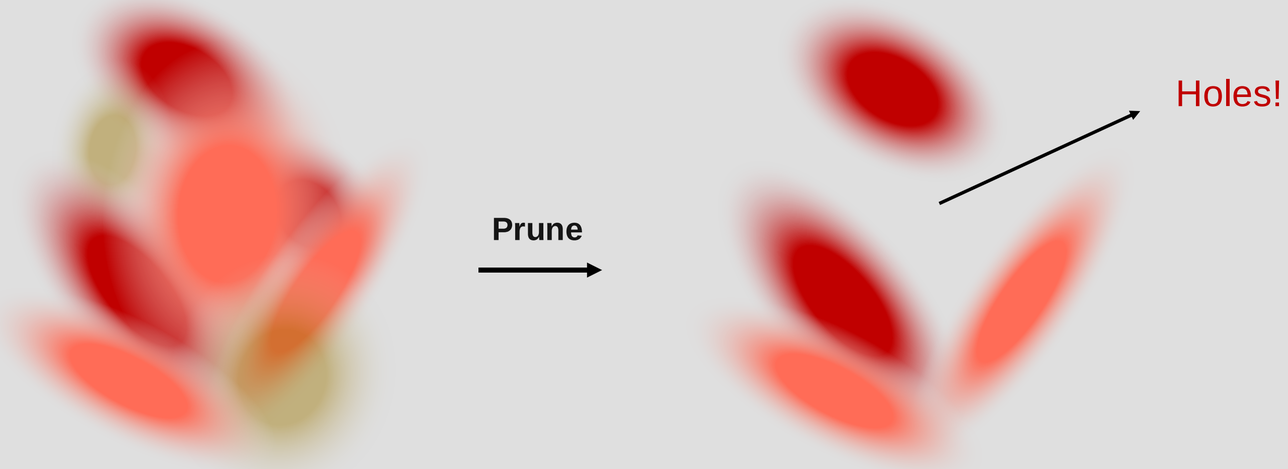


Polynomial Regression Models

7.35 MB

Patch

- **Patch Splats**
  - Smoother features
  - Sparsely modelled
- **Error-Sensitive**

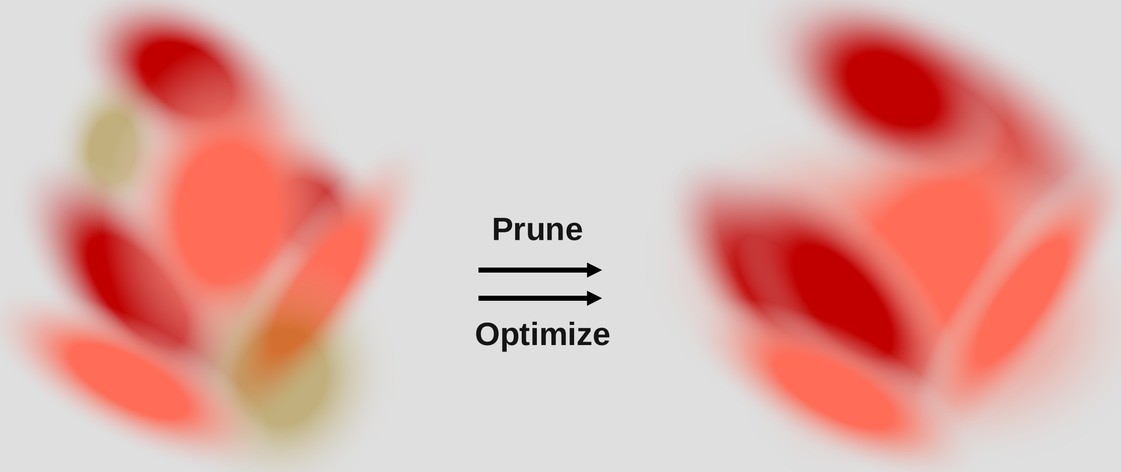


Patch Splats

Pruned Splats

Patch

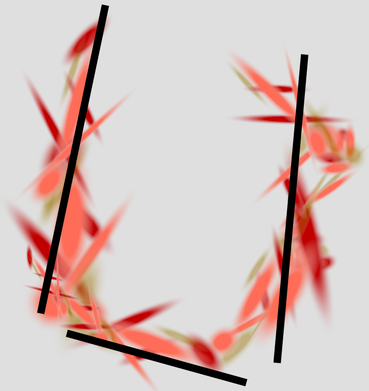
- **Patch Splats**
  - Smoother features
  - Sparsely modeled
- **Error-Sensitive**



Patch Splats

Pruned and Optimized Splats

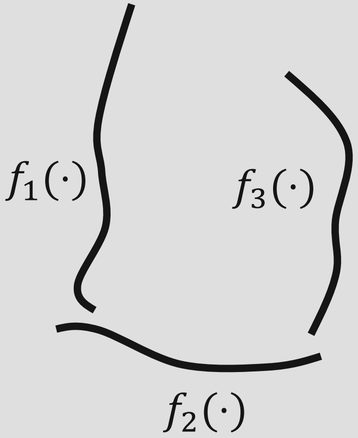
Sketch & Patch



Sketch Splats

Encoding

Decoding



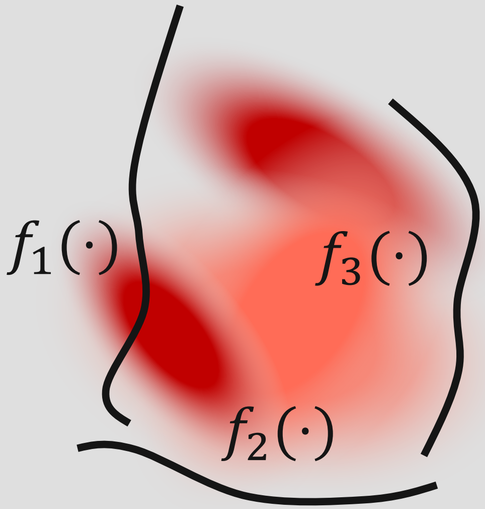
Parametric Models

Patch Splats

Prune

Optimize

Pruned and Optimized Splats



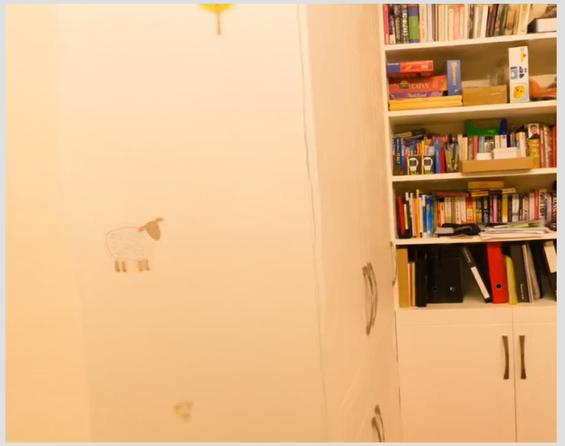
Hybrid Representation

Store or Transmit

Experimental Setup

- **Datasets:** Four representative scenes
- **Metrics:** PSNR, SSIM, LPIPS
- **Comparisons:**
  - ***Baseline***. Change *densification threshold* to control the model size
  - ***Prune&Retrain*** (Ablation). *Uniformly down-sample* the 3DGS and optimize them.
  - ***Sketch*** (Ablation). Only encoding Sketch Splats.

Playroom

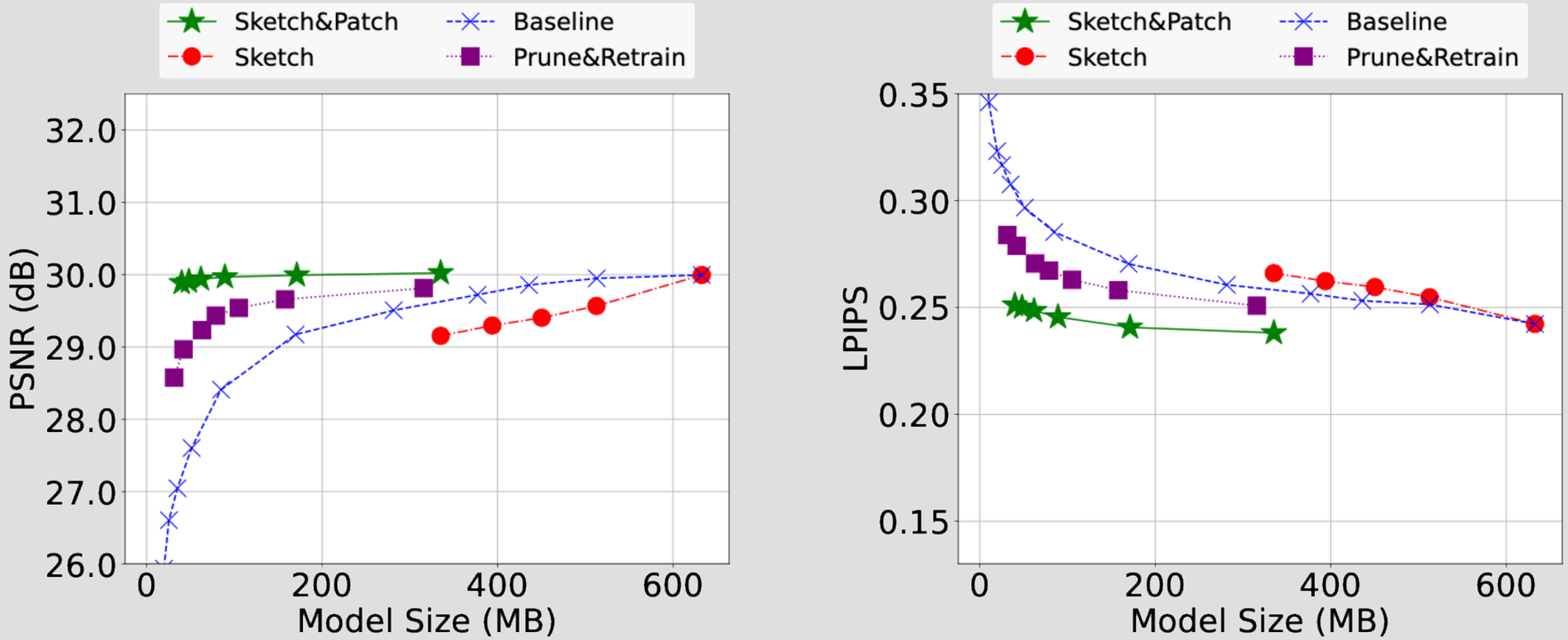


Drjohnson

Room

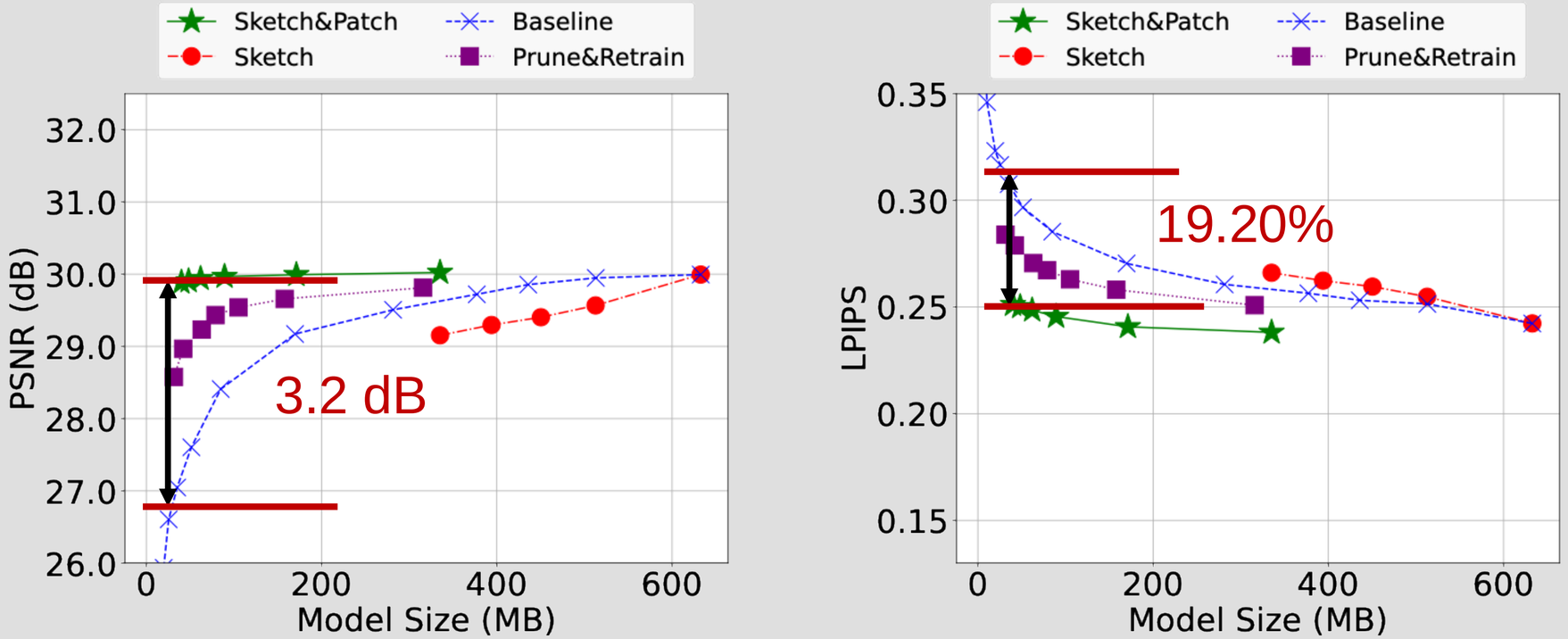
Truck

Performance: Rate-Distortion Tradeoff



Playroom

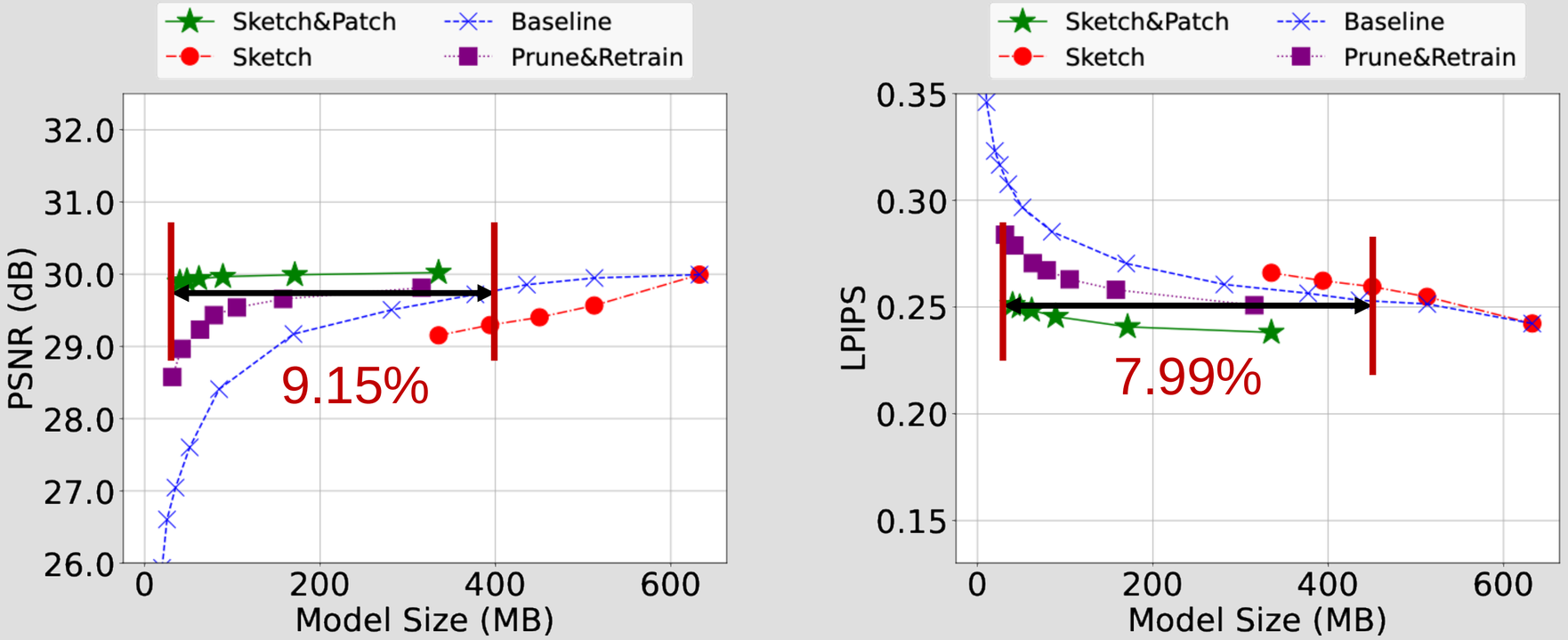
Performance: Rate-Distortion Tradeoff



Playroom

- **At the same model size**: Improvement up to 3.2 dB (PSNR) and 20% (LPIPS)

Performance: Rate-Distortion Tradeoff

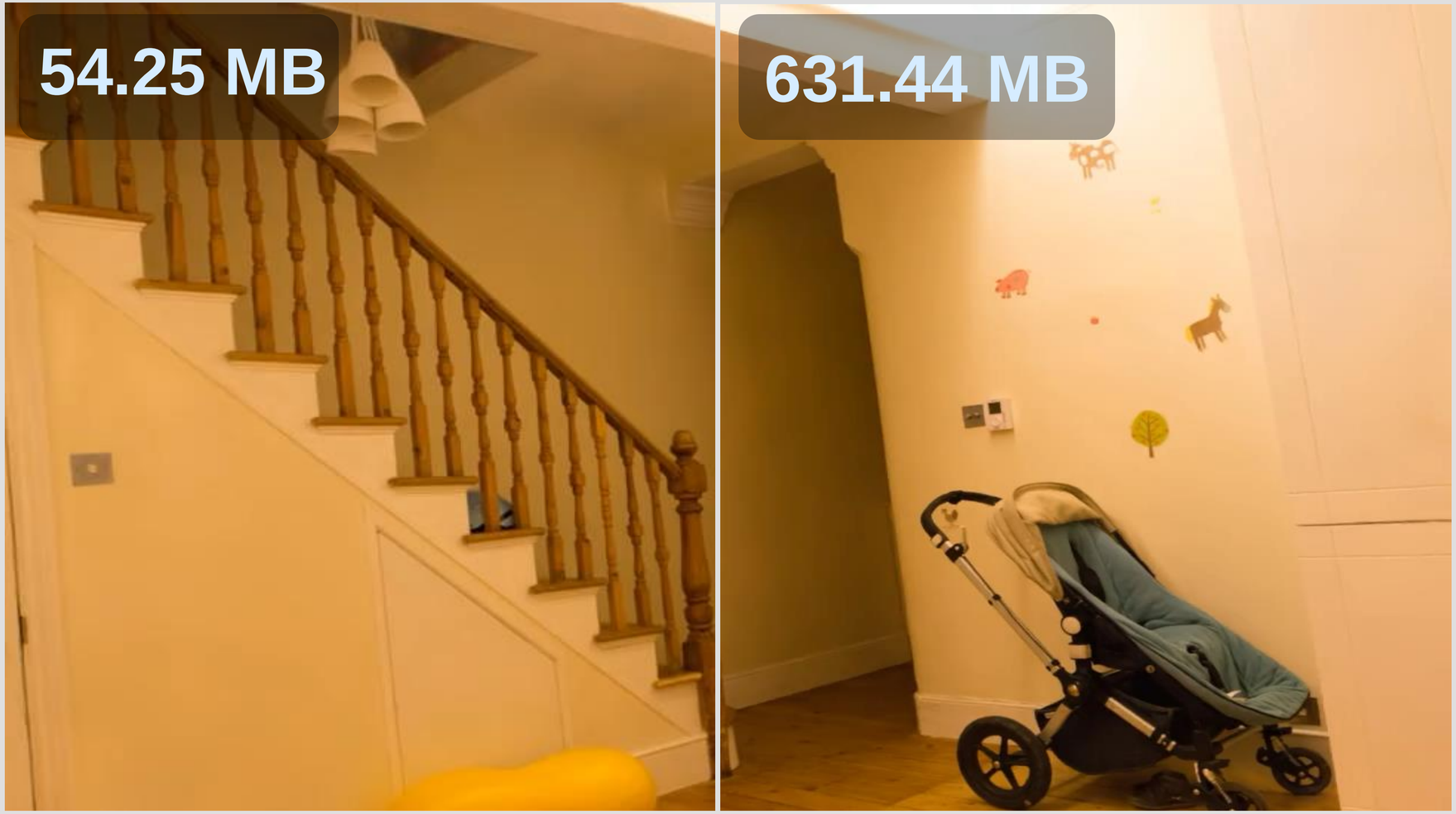


Playroom

- **At the same model size**: Improvement up to 3.2 dB (PSNR) and 20% (LPIPS)
- **At the same visual quality**: Only need 9% (PSNR) and 8% (LPIPS) of the size

Performance: Visualization

SSIM: 0.91

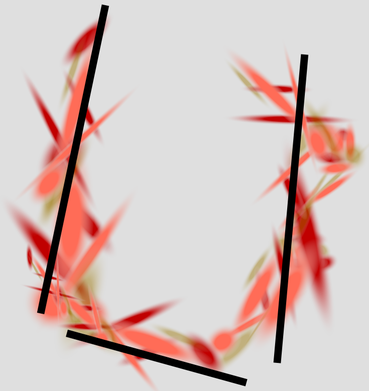


S&P Compression **Raw 3DGS**

Future Work

Can we further compress?

(Thousands of 3DGS Compression Works)



Sketch Splats

Encoding

Decoding

$f_1(\cdot)$ $f_3(\cdot)$ $f_2(\cdot)$

Parametric Models

$f_1(\cdot)$ $f_3(\cdot)$ $f_2(\cdot)$

Hybrid Representation

Store or Transmit

Patch Splats

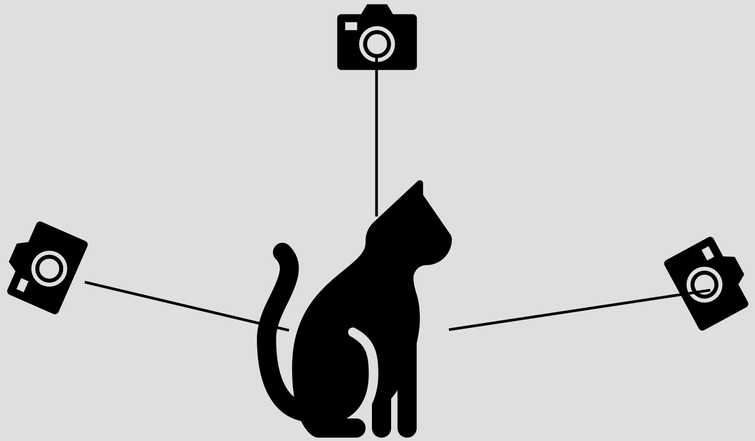
Prune

Optimize

Pruned and Optimized Splats

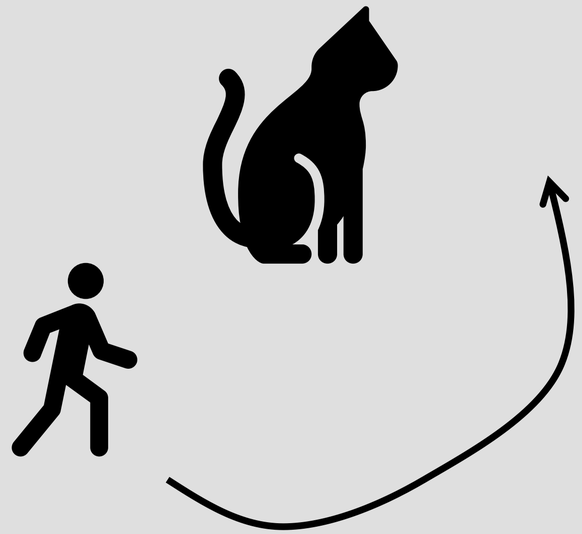
Future Work

- **Current Evaluation**
  - Projection-based method with 2D metrics



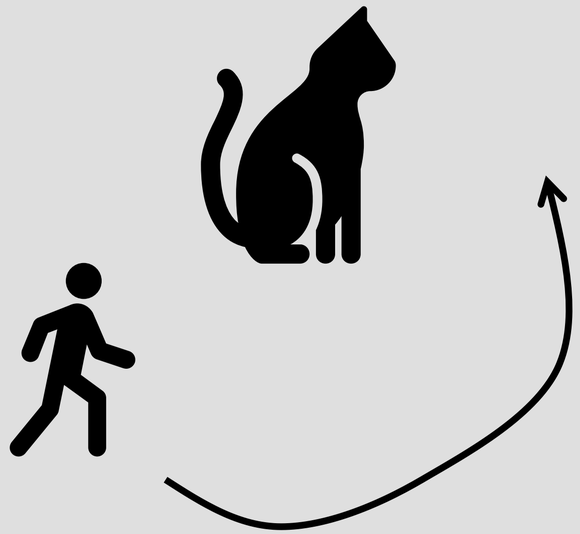
Future Work

- **Current Evaluation**
  - Projection-based method with 2D metrics
- **Interaction in Immersive Media**



Future Work

- **Current Evaluation**
  - Projection-based method with 2D metrics
- **Interaction in Immersive Media**
  - Spatial Consistency
  - View Dependency
  - Interaction Complexity



Sketch and Patch: Efficient 3D Gaussian Representation for Man-Made Scenes

MMVE'25, Stellenbosch

Yuang Shi, Simone Gasparini, Géraldine Morin, Chenggang Yang, Wei Tsang Ooi