Qualcomm

ICLR
International Conference On Learning Representations

Sort-free Gaussian Splatting via Weighted Sum Rendering

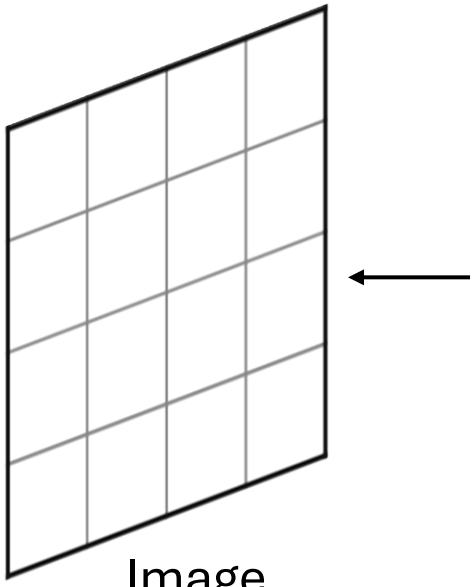
Qiqi Hou [1], Randall Rauwendaal [2], Zifeng Li [2], Hoang Le [1], Farzad Farhadzadeh [1], Fatih Porikli [1], Alexei Bourd [2], Amir Said[*1]

[1] Qualcomm AI Research[†] [2] Graphic Research Team

* Corresponding author
† Qualcomm AI Research is an initiative of Qualcomm Technologies, Inc

Motivation

Qualcomm AI Research



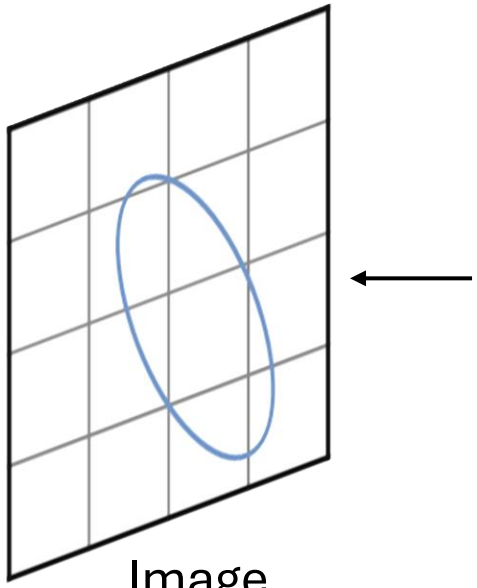
Image

Gaussians

Gaussian Splatting

Motivation

Qualcomm AI Research



Image

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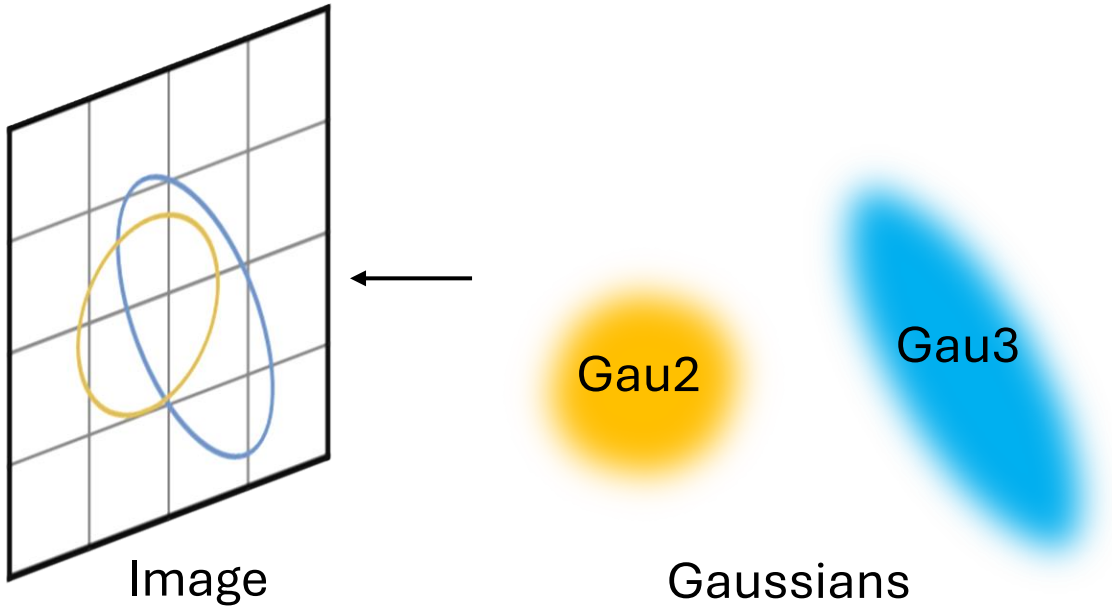
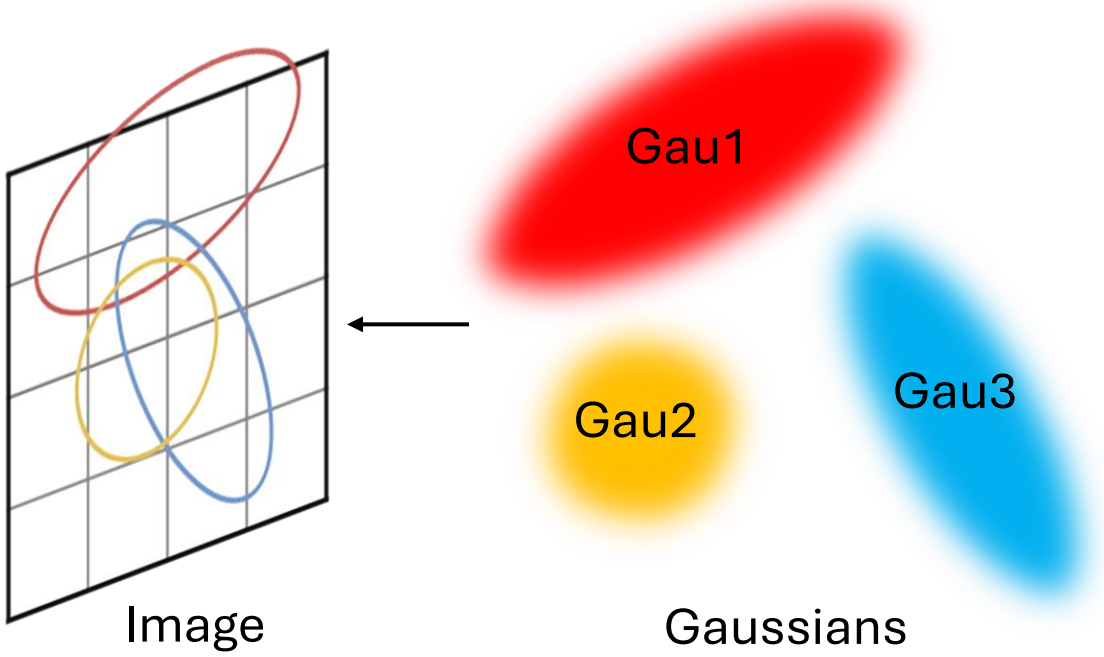


Gaussian Splatting

Motivation

Qualcomm AI Research



Gaussian Splatting

Motivation

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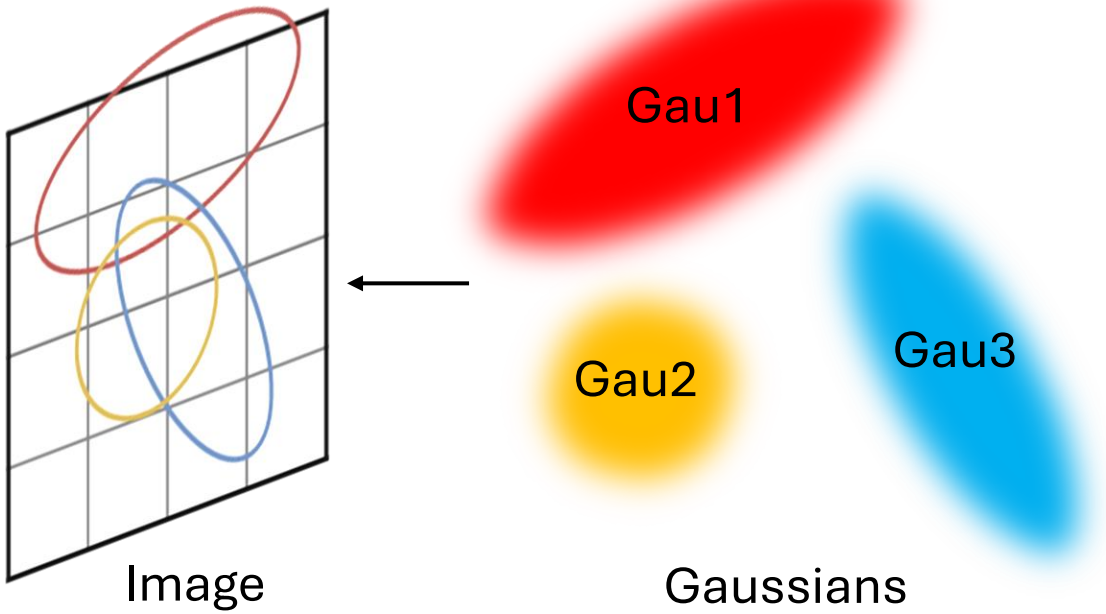
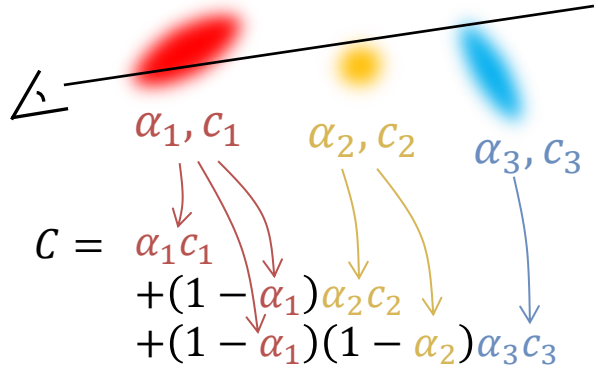
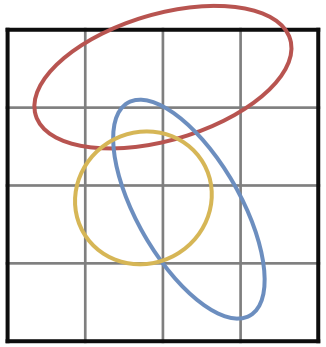




Gaussian Splatting

Motivation

Qualcomm AI Research

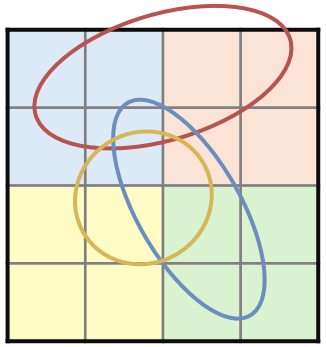


Tiling

Gaussian Splatting Rendering

3DGS splits the rendered image into multiple non-overlapping tiles.

Motivation



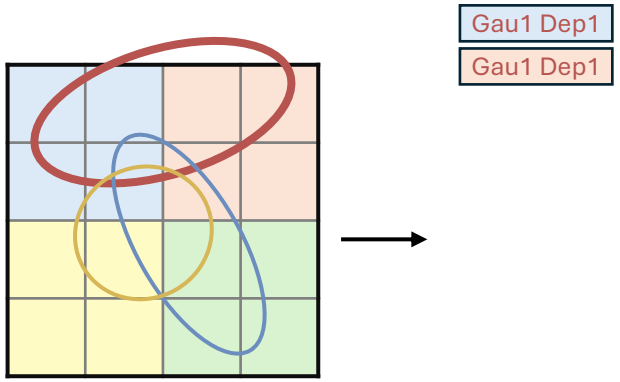
Tiling

e.g. 16 x 16 pixels

Tiling

3DGS splits the rendered image into multiple non-overlapping tiles.

Motivation

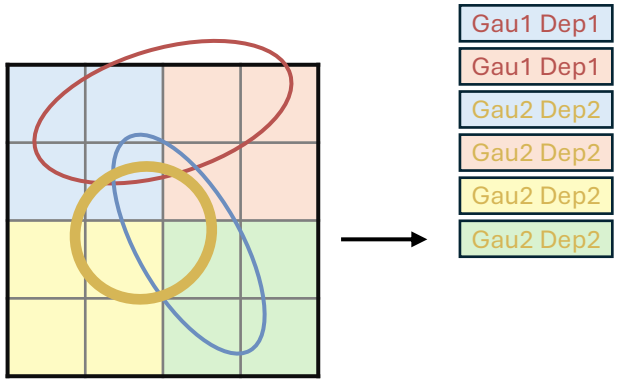


Tiling Replication

Replication

Gaussians that span across multiple tiles being duplicated accordingly

Motivation



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Motivation

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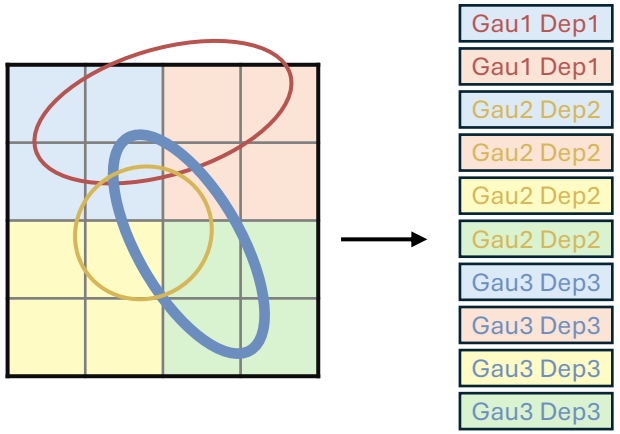

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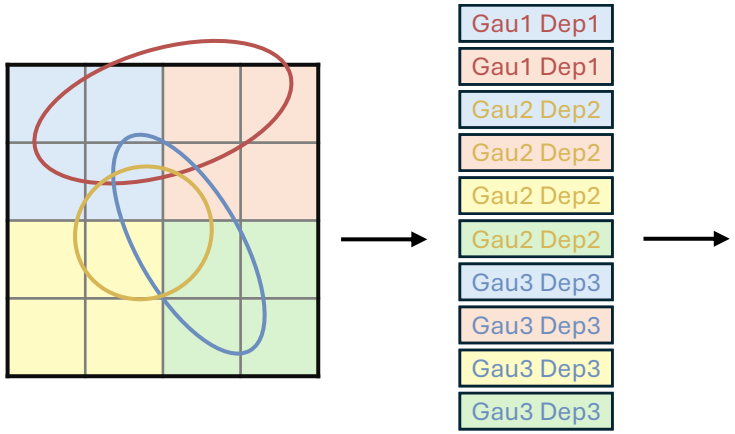
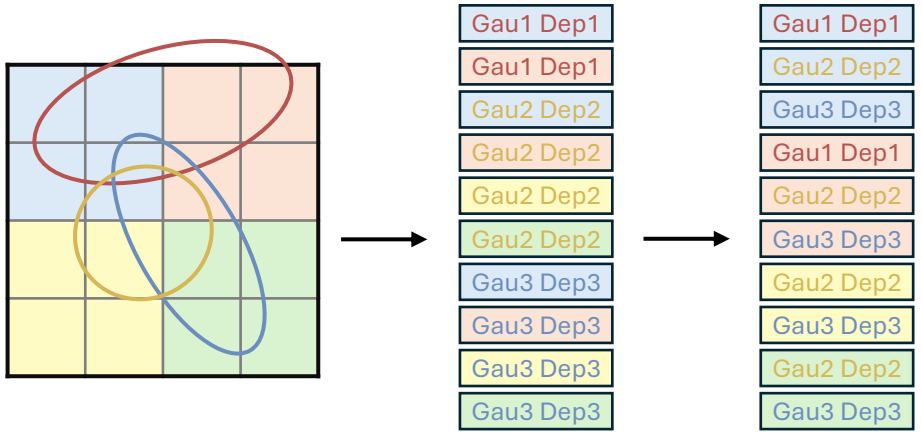


Sorting

3DGS sort the Gaussians according to the depth.

Motivation



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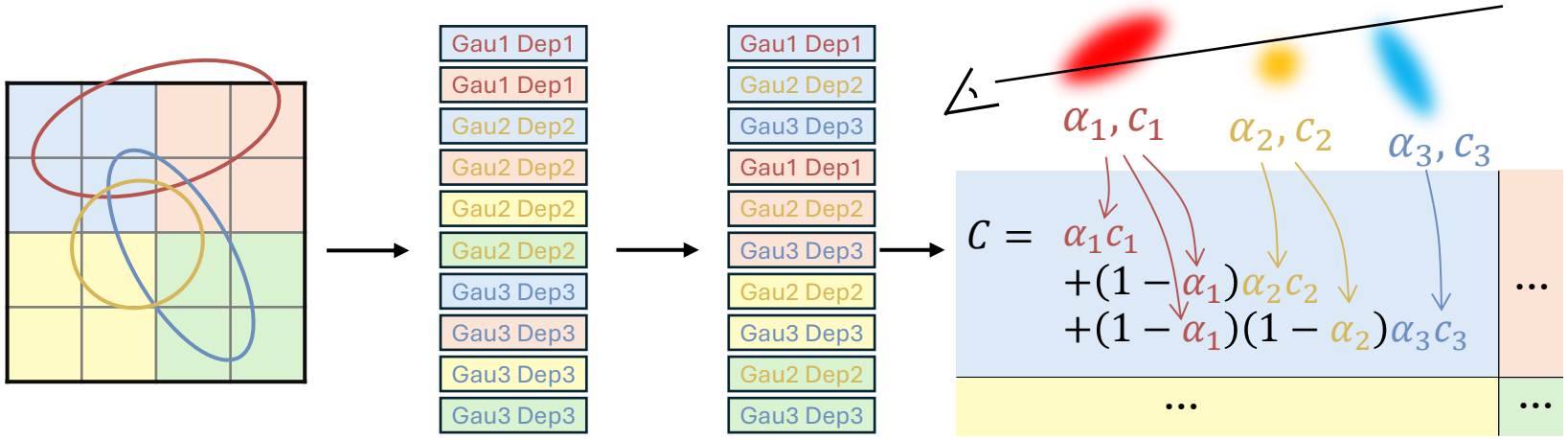
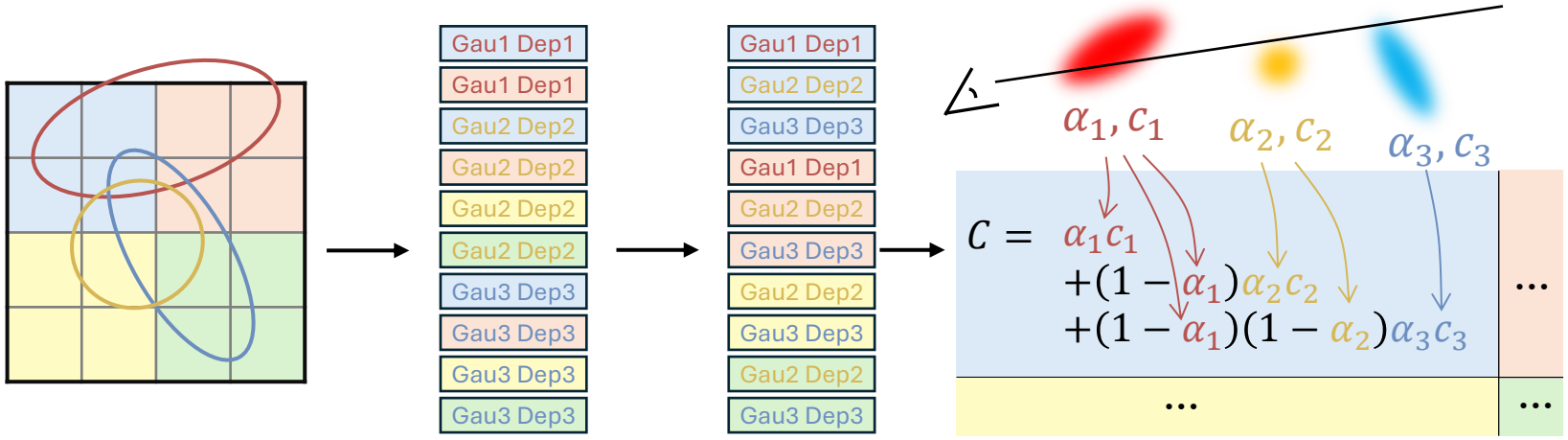


Alpha blending

3DGS relies on non-commutative alpha blending.

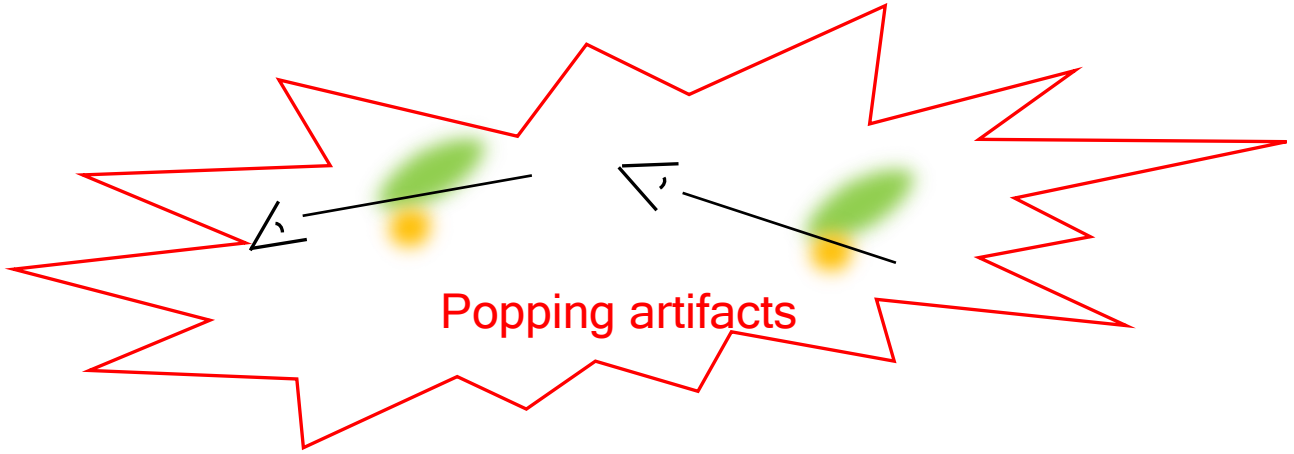
Motivation

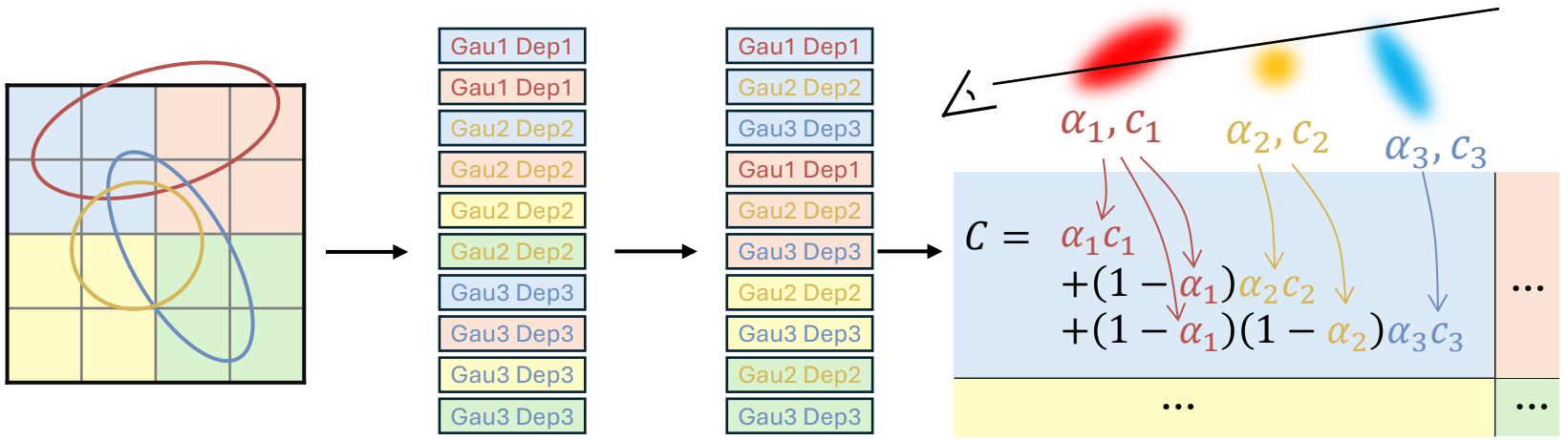


Sorting is not friendly for GPU Hardware Rasterization

It introduces computational overhead and memory bottlenecks.

Motivation





Tiling Replication **Sorting** Rendering

Sorting introduces popping artifacts

Our method

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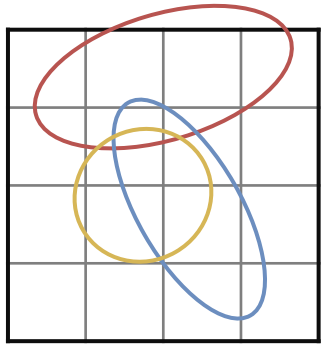

Can we remove sorting in 3DGS?

Our method

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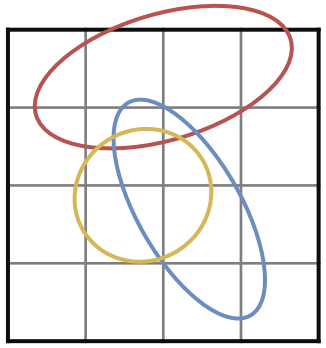
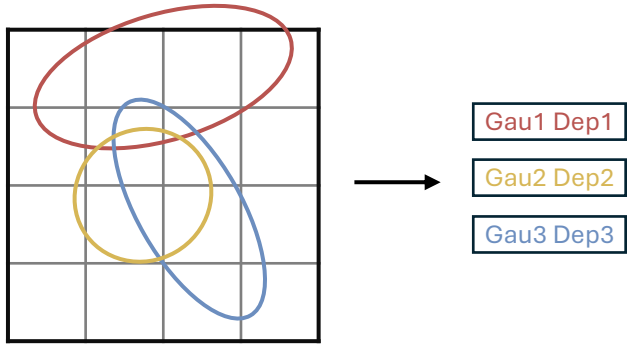


Sort-free Gaussian Splatting

Our method

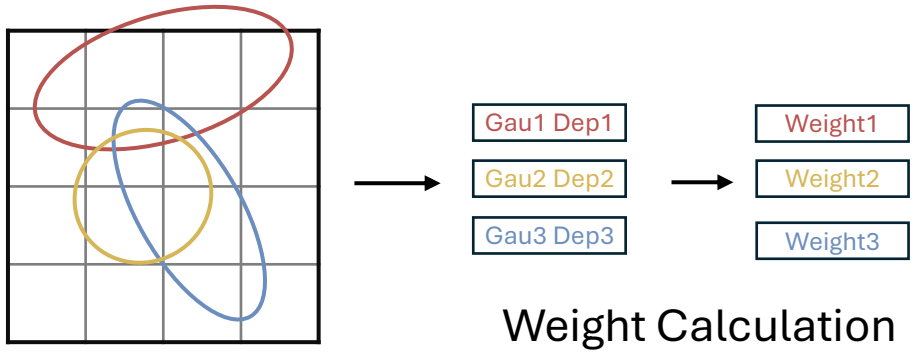
Qualcomm AI Research



Sort-free Gaussian Splatting

Our method

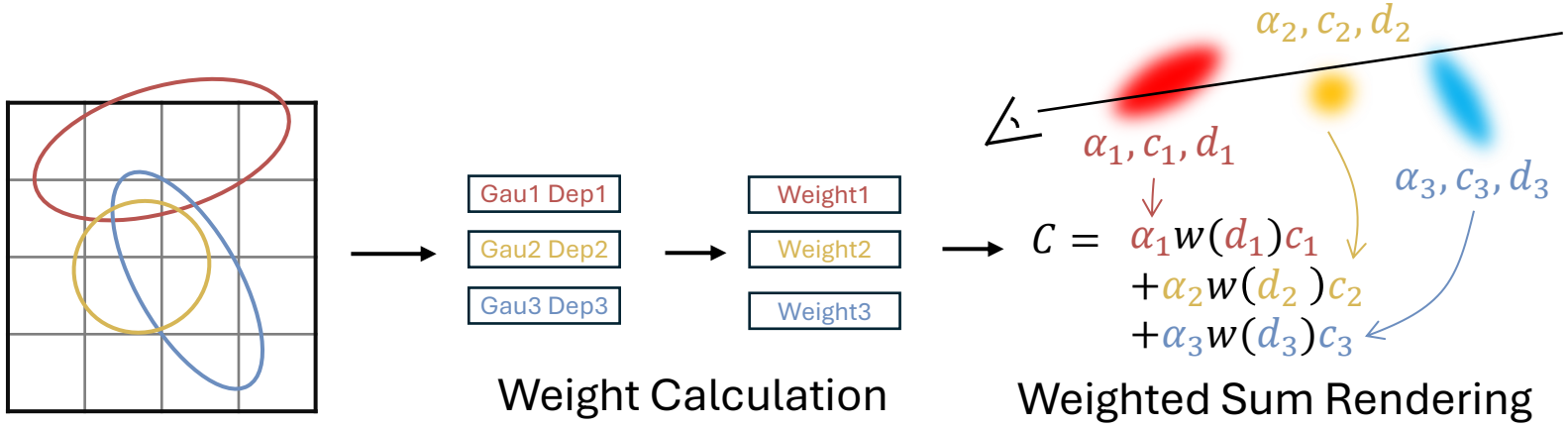
Qualcomm AI Research



Sort-free Gaussian Splatting

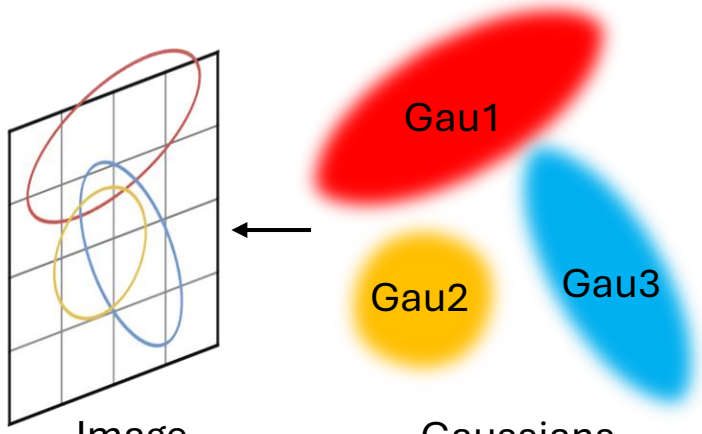
Our method

Qualcomm AI Research

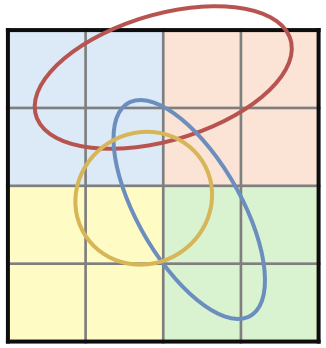


Sort-free Gaussian Splatting

Our method

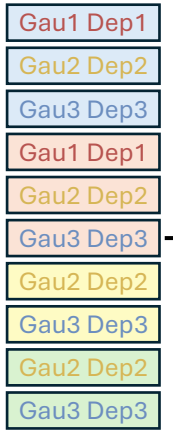


Splatting

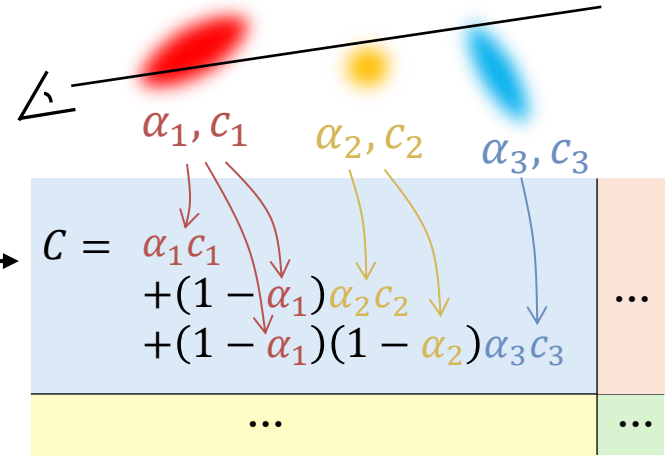


Tiling

Replication



Sorting



Rendering

3DGS with sort

Sort-free Gaussian Splatting via Weighted Sum Rendering

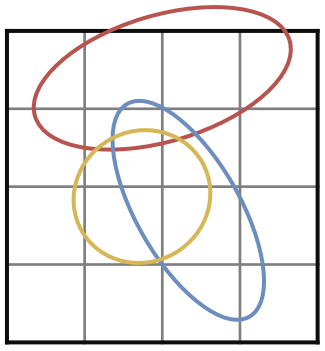
Gaussians

Pixel

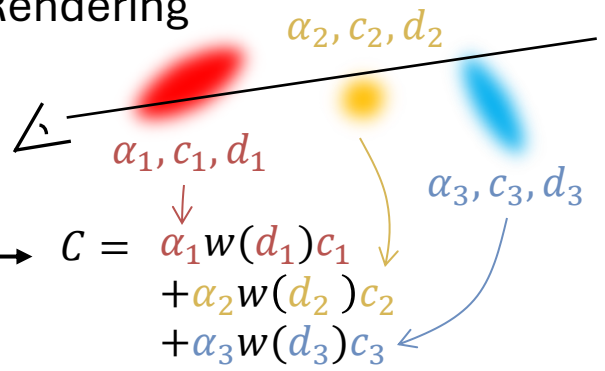
Tiles

Gaussian 1 for the blue tile with depth 1

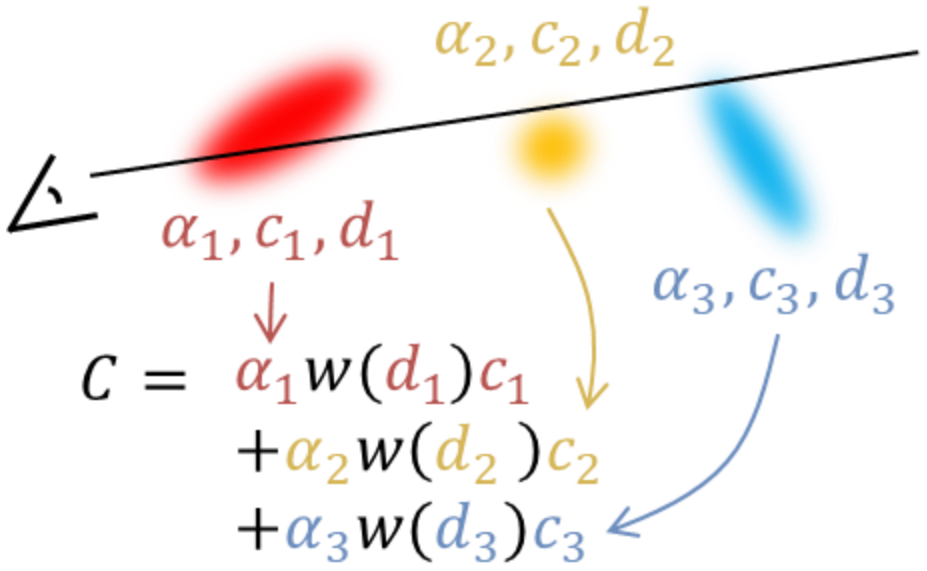
α Alpha c Color d Depth



Weight Calculation



Weighted Sum Rendering



$$\mathbf{C} = \frac{\mathbf{c}_B w_B + \sum_{i=1}^{N} \mathbf{c}_i \alpha_i w(d_i)}{w_B + \sum_{i=1}^{N} \alpha_i w(d_i)}$$

Weighted Sum Rendering

How to define the weight function w(d), and alpha?

WSR

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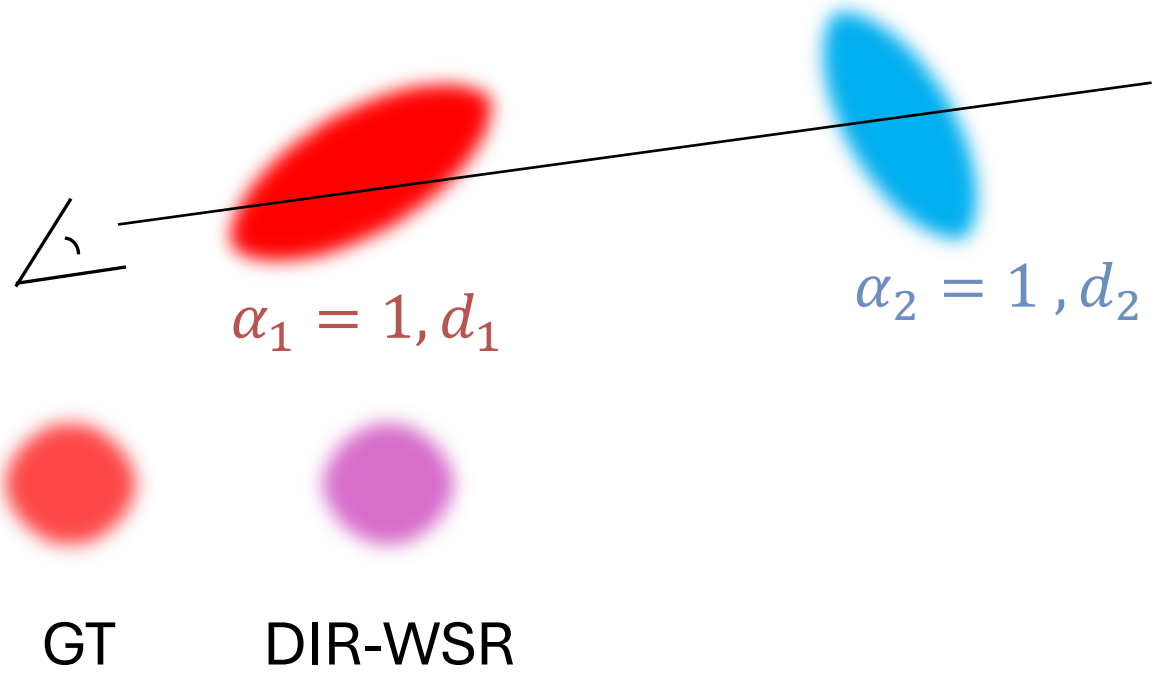

$$w(d_i) = 1$$

Direct Weighted Sum Rendering

No learnable parameter.

WSR

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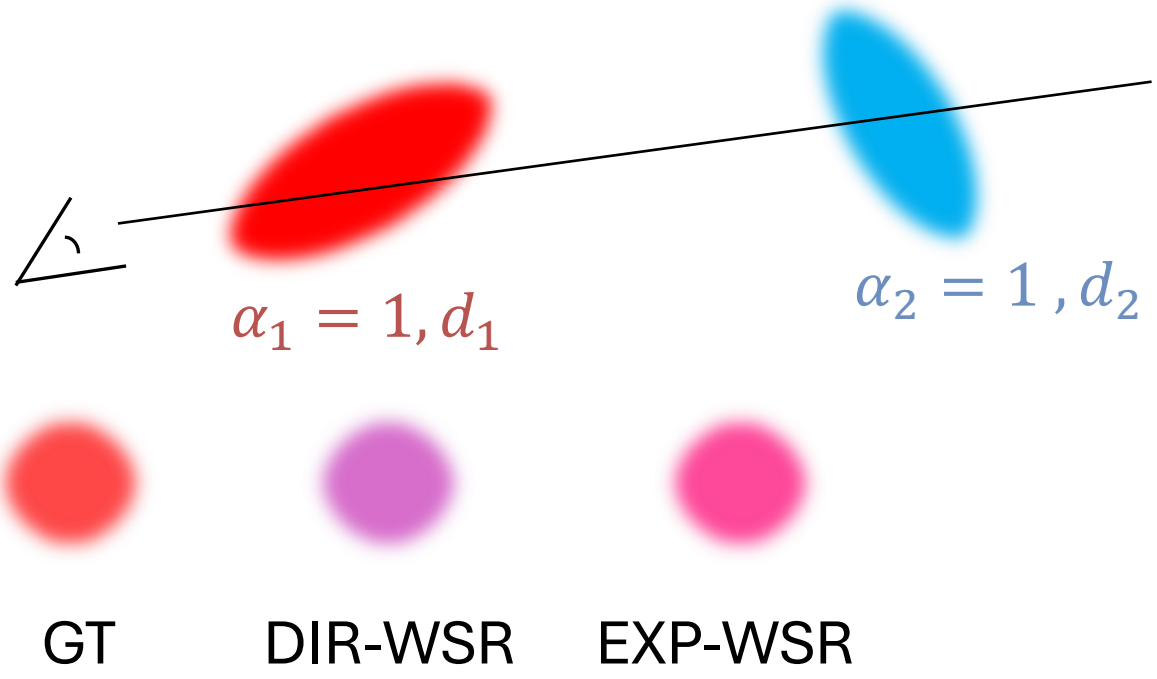

$$w(d_i) = \exp(-\sigma d_i^{\beta})$$

Exponential Weighted Sum Rendering

Learnable parameters σ and β enable to produce more accurate results.

WSR

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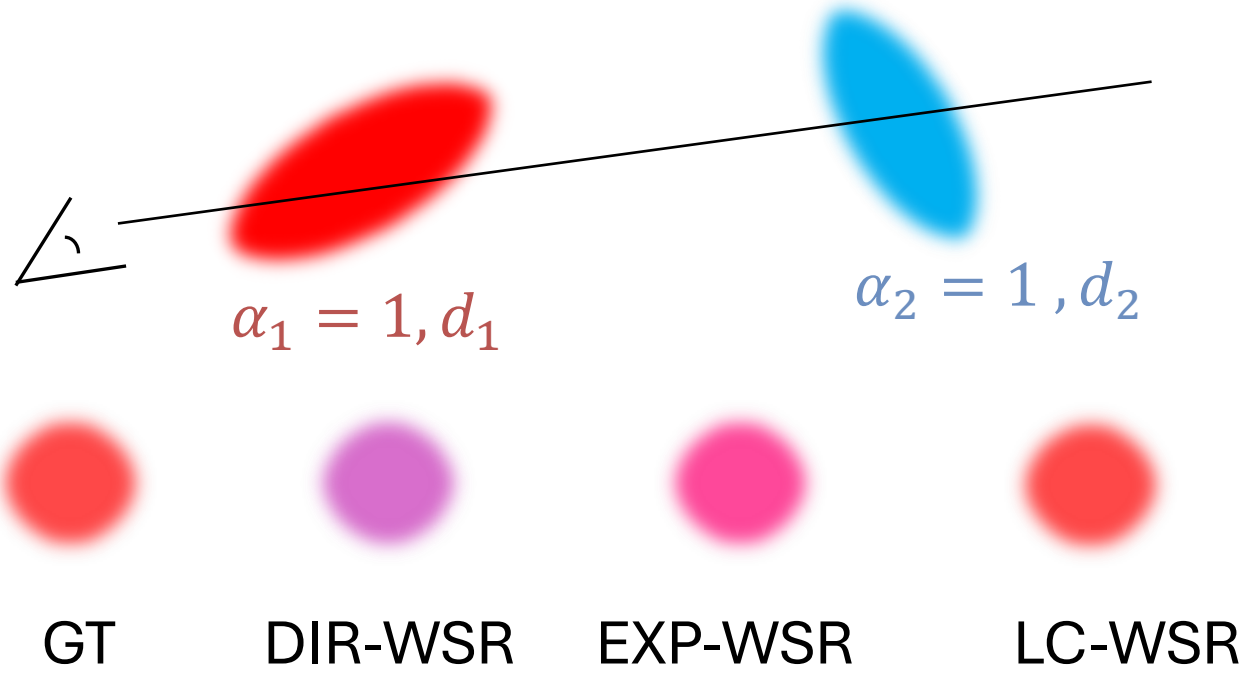
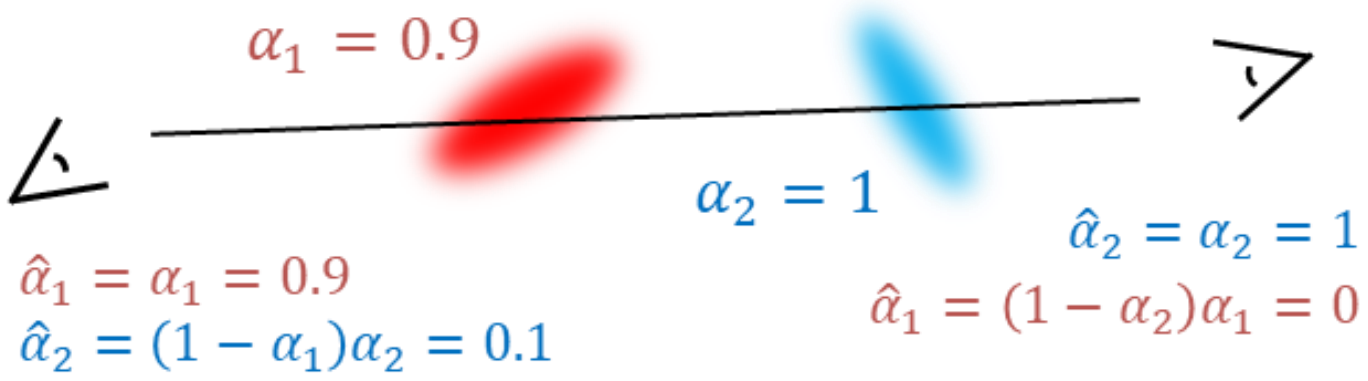


$$w(d_i) = \max\left(0, 1 - \frac{d_i}{\sigma}\right) v_i$$

Linear Correction Weighted Sum Rendering

ReLU like function. Never used in OIT. We are the first to use it in rendering.

View dependent opacity



$$u_i = Y(\|\mathbf{f} - \mathbf{p}_i\|, \mathbf{H}_i)$$

View dependent opacity

Y (·) indicates the spherical harmonic function and $\mathbf{H}_i$ indicates the learnable spherical harmonics coefficients for opacity.

Experiments

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Method	Mip-NeRF 360			Tanks & Temples			Deep Blending		
	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓
Plenoxels	23.08	0.626	0.463	21.08	0.719	0.379	23.06	0.795	0.510
INGP-Base	25.30	0.671	0.371	21.72	0.723	0.330	23.62	0.797	0.423
INGP-Big	25.59	0.699	0.331	21.92	0.745	0.305	24.96	0.817	0.390
M-NeRF360	**27.69**	0.792	0.237	22.22	0.759	0.257	29.40	0.901	0.245
3DGS	27.21	**0.815**	0.214	23.14	0.841	0.183	29.41	**0.903**	0.243
LC-WSR	27.19	0.804	**0.211**	**23.61**	**0.842**	**0.177**	**29.63**	0.902	**0.229**

Quantitative Results

Experiments

Qualcomm AI Research

Qualitative Results

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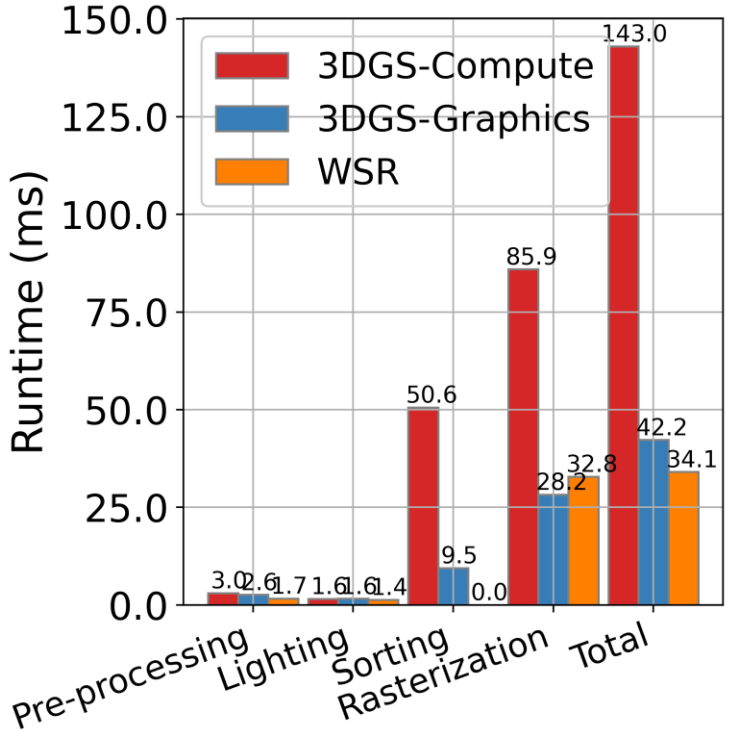
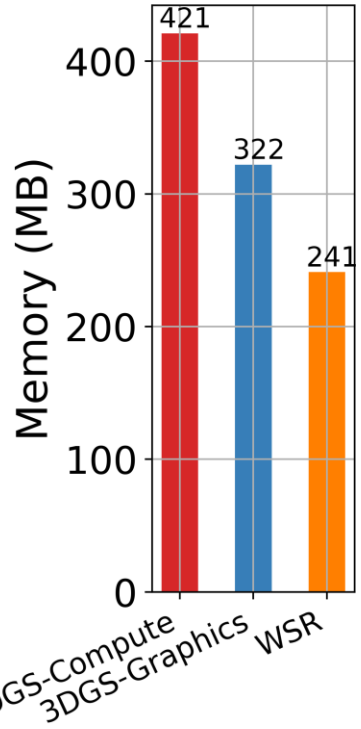
Experiments

3DGS-Compute: Port 3DGS CUDA kernels to Vulkan compute shaders

3DGS-Graphics: Global sorting followed by hardware rasterization



Runtime Comparison



Memory Comparison

On Snapdragon 8 gen 3 at 1920x1080

Pop Artifacts

Moving along z-direction

Thank you!

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