SaLF: Sparse Local Fields for Multi-Sensor Rendering in Real-Time

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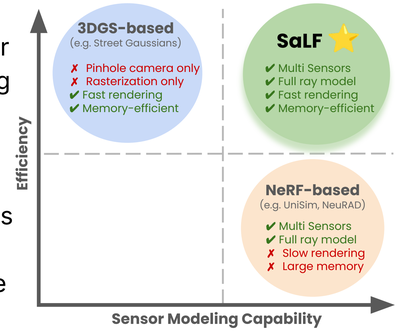
Motivation: Unified Multi-Sensor Simulation

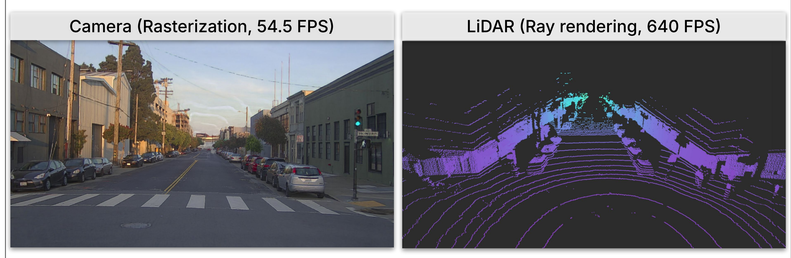
+ High-fidelity camera and LiDAR simulation is critical for autonomy testing and training
+ NeRFs support flexible ray-based sensors, but are slow to train and render
+ 3DGS is efficient, but requires additional approximations when moving beyond pinhole cameras



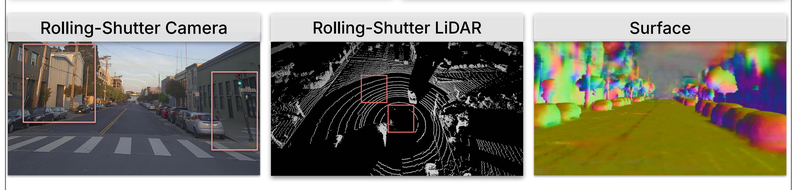
Goal: a unified representation supporting both **rasterization** and **ray-based rendering**

Applications

+ **Efficient and flexible multi-sensor simulation**



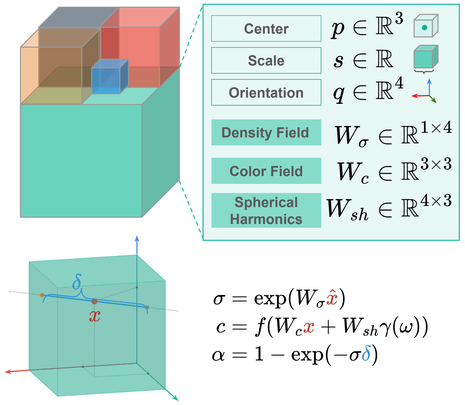
Multi-sensor rendering in real-time



Advanced sensor modeling via ray rendering

Representation

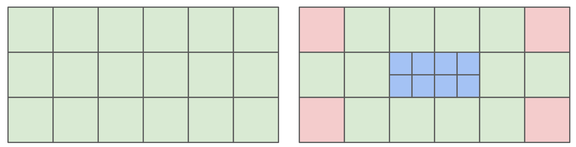
SaLF uses sparse local implicit voxel fields backed by an octree to enable efficient rasterization and ray rendering.



$$\sigma = \exp(W_\sigma \hat{x})$$
$$c = f(W_c x + W_{sh}\gamma(\omega))$$
$$\alpha = 1 - \exp(-\sigma\delta)$$

Adaptive density control

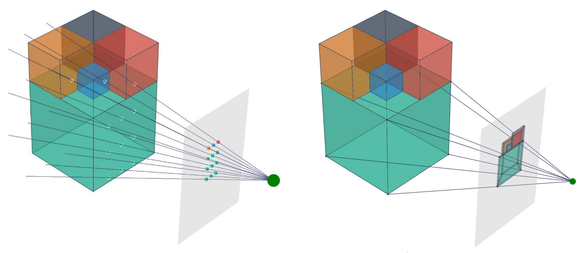
Coarse-to-fine voxel densification subdivides high gradient regions and prunes empty space.



Dense Initialization — Prune and Split

Rendering

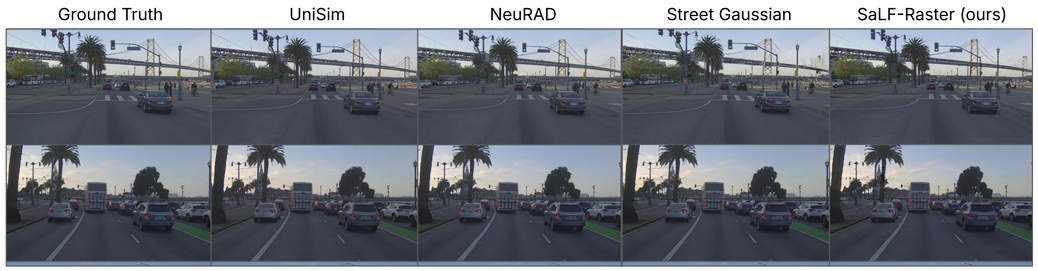
One representation supports fast pinhole rasterization as well as flexible ray-based rendering.

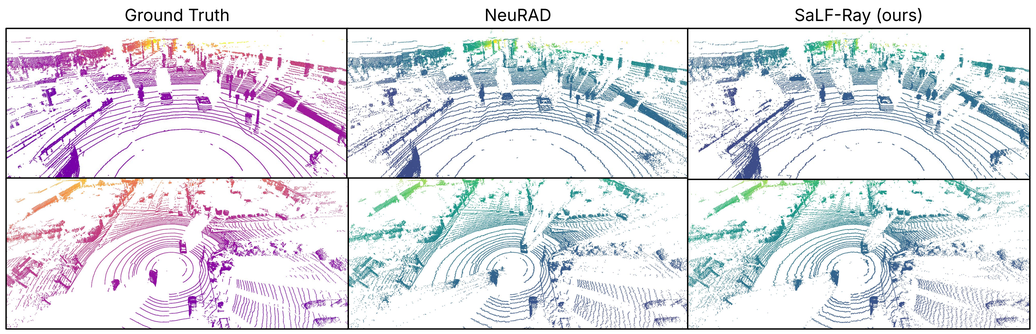


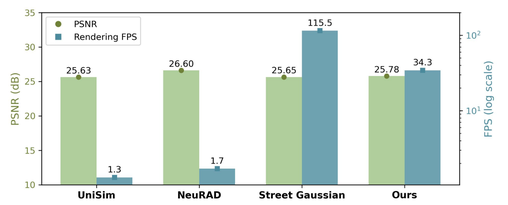
Octree-accelerated ray rendering — Tile-based rasterization

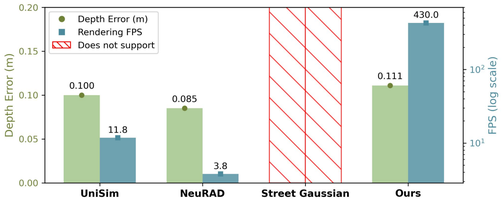
Results

+ **NVS comparison with SOTA**









+ **Ablation**

Ablation study on SaLF components.

Models	PSNR↑	SSIM↑	LPIPS↓
Ours	**25.48**	**0.744**	**0.373**
– Densification	23.19	0.670	0.474
– Field matrices	25.11	0.735	0.386

+ **Autonomy Evaluation**

Downstream domain gap evaluation.

	Det. Agg. ↑	Pred. ADE ↓	Plan Cons. ↓
UniSim	0.74	0.63	0.99
Ours	**0.78**	**0.52**	**0.83**

+ **Limitations:**
  + Requires higher primitive count compared to 3DGS for similar quality
  + Does not support non-rigid and temporal changes in the representation

+ **References**

[UniSim] Z. Yang, Y. Chen, J. Wang, S. Manivasagam, W.-C. Ma, A. J. Yang, R. Urtasun
Unisim: A neural closed-loop sensor simulator, CVPR 2023
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[Street Gaussian] Y. Yan, H. Lin, C. Zhou, W. Wang, H. Sun, K. Zhan, X. Lang, X. Zhou, S. Peng
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(* equal contribution)