HUG: Hierarchical Urban Gaussian Splatting with Block-Based Reconstruction for Large-Scale Aerial Scenes

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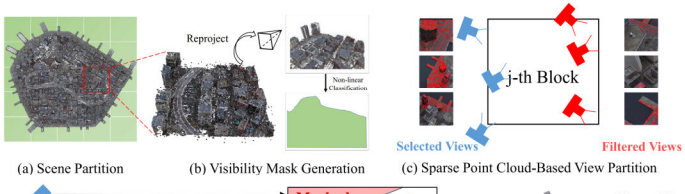
Pipeline: Block-Based Gaussian Reconstruction



An overview of **HUG**. **(a).** The sparse point cloud from COLMAP is used to uniformly partition the scene into blocks. **(b).** For each view, visibility masks for all blocks are generated by reprojecting 3D points within blocks into the image space and segmenting corresponding visible regions. **(c).** Views are assigned to training block *j* if the visible sparse point cloud exceeds a threshold. **(d).** During training each block, anchors within the view frustum are selected based on their position and level. These selected anchors infer the neural Gaussians used for rendering and are optimized using our hierarchical weighted image supervision along with other constraints. **(e).** All trained blocks are seamlessly merged and rendered.

Contributions:

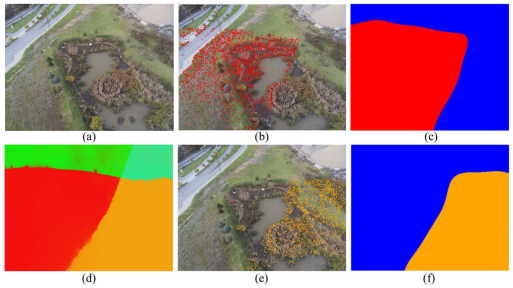
- A simple and effective visibility-based partitioning strategy
- Hierarchical neural Gaussian representation tailored for block-based reconstruction
- Several effective training strategies

Visibility-Based View Partitioning

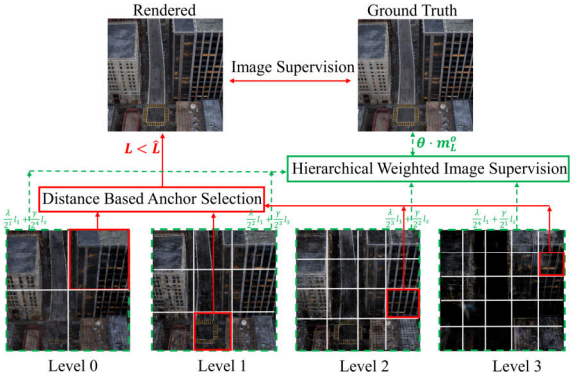
An image I_i is included in the training set $\mathcal{T}_j$ for block *j* if the number of visible points exceeds a threshold τ_p:

$$I_i \in \mathcal{T}_j \quad \text{if} \quad \sum_{p \in P_j} \mathbb{I}(V(p, I_i)) > \tau_p$$

Visibility Mask Generation



Hierarchical Weighted Image Supervision



Dynamic Gradient Threshold

The gradient threshold for splitting is gradually decreased during training: $\tau_g(i) = \tau_g \cdot \eta^{\lfloor i/M \rfloor}$, where i is the current iteration number, M is the interval, and η is the decrease rate.

Qualitative comparison

Quantitative comparison

	MatrixCity			Residence			Rubble			Building			Sci-Art		
Metrics	SSIM↑	PSNR↑	LPIPS↓	SSIM↑	PSNR↑	LPIPS↓	SSIM↑	PSNR↑	LPIPS↓	SSIM↑	PSNR↑	LPIPS↓	SSIM↑	PSNR↑	LPIPS↓
MegaNeRF [33]	-	-	-	0.628	22.08	0.489	0.553	24.06	0.516	0.547	20.93	0.504	0.770	25.60	0.390
3DGS [11]	0.735	23.67	0.384	0.791	21.44	0.236	0.777	25.47	0.277	0.720	20.46	0.305	0.830	21.05	0.242
Octree-GS [26]	0.814	26.41	0.282	-	-	-	-	-	-	-	-	-	-	-	-
Hier-GS [12]	0.842	26.67	0.251	0.776	20.24	0.221	0.765	22.28	0.257	0.733	20.04	0.262	0.828	19.74	0.207
VastGS [15]	-	-	-	0.777	20.38	0.247	0.766	25.10	0.294	0.740	21.69	0.293	0.809	21.66	0.269
CityGS [17]	0.865	27.46	0.204	0.813	22.00	0.211	0.813	25.77	0.228	0.778	21.55	0.246	0.837	21.39	0.230
Ours	0.883	28.02	0.142	0.813	22.33	0.207	0.839	26.42	0.197	0.792	22.35	0.228	0.846	21.83	0.204

*best scores red, second best orange, third best yellow