Splatter-360: Generalizable 360 Gaussian Splatting for Wide-baseline Panoramic Images

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1. Introduction

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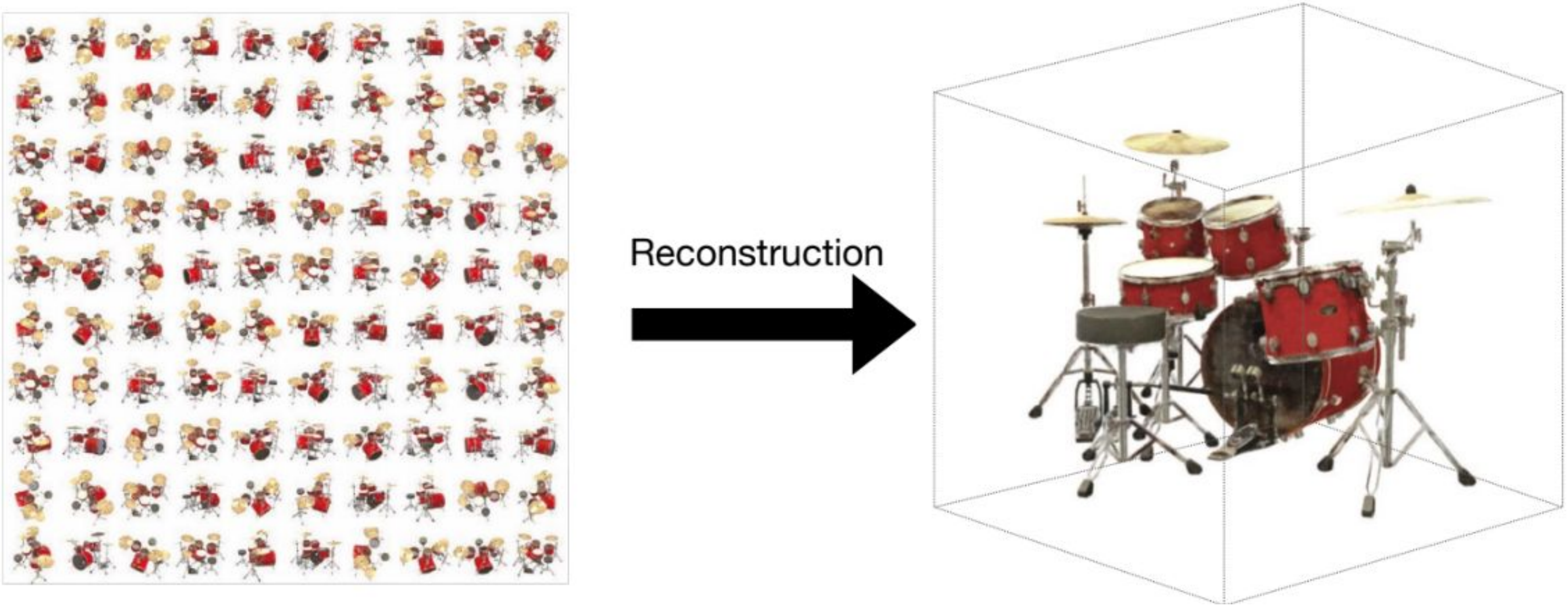
- 3D Reconstruction aims to retrieve a 3D object
  - Collection of Views (with camera parameters)
  - Obtain a representation of the 3D object

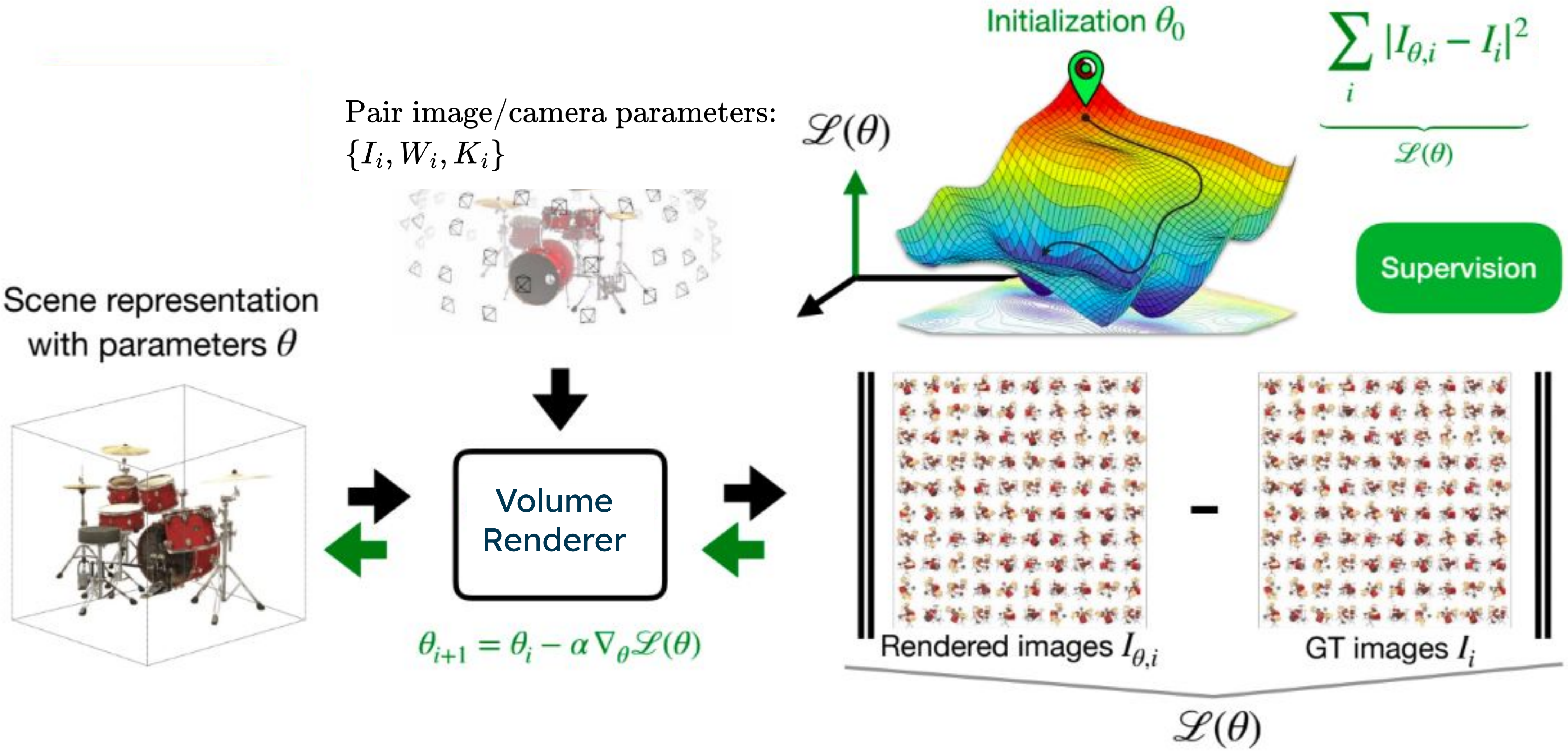


1. Introduction

- Revolutionized by 3D Gaussian Splatting
  - 3D Reconstruction technique
  - Represents the scene as 3D Gaussians
  - Fast and high-quality rendering

Kerbl, Bernhard, et al. "3D Gaussian Splatting for Real-Time Radiance Field Rendering." ACM Trans. Graph. 42.4 (2023): 139-1.

1. Introduction :: 3DGS

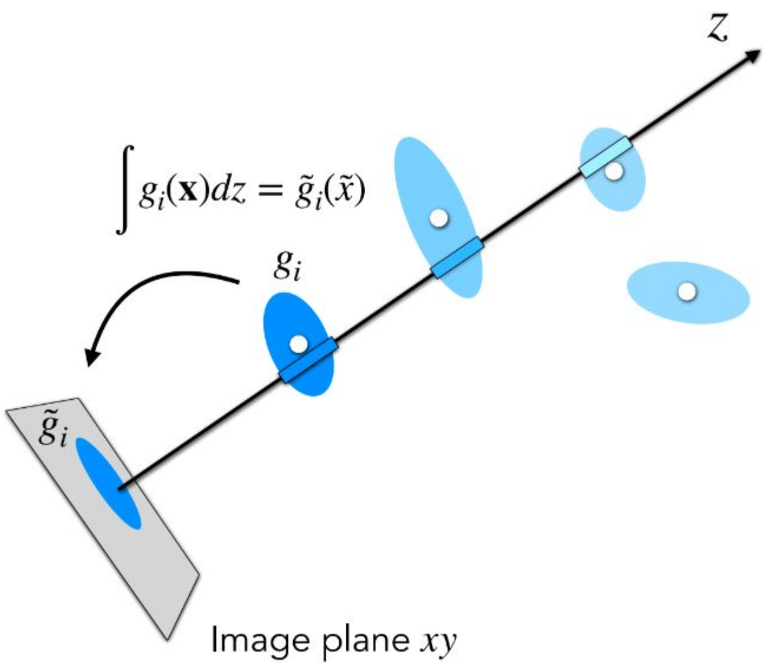


Assume you have the N Gaussians ordered in the ray
And the Gaussians $g_i = (\Sigma_i, \mu_i, \sigma_i, c_i)$

Project the gaussians $\tilde{g}_i = \left(\tilde{\Sigma}_i, \tilde{\mu}_i, \tilde{\sigma}_i, c_i\right)$

$$I_f \approx \sum_i^N c_i \tilde{\sigma}_i \exp\left(-\frac{1}{2}(p - \tilde{\mu}_i)^T \tilde{\Sigma}_i^{-1}(p - \tilde{\mu}_i)\right) T_i(p)$$

Where $T_i(p) = \prod_{j=0}^{i-1} (1 - \tilde{\sigma}_j \exp\left(-\frac{1}{2}(p - \tilde{\mu}_j)^T \tilde{\Sigma}_j^{-1}(p - \tilde{\mu}_j)\right))$



1. Introduction :: 360 Images

- Created for "common" images
  - Not for "wide-angle" images
  - However, some techniques adapted to this setting

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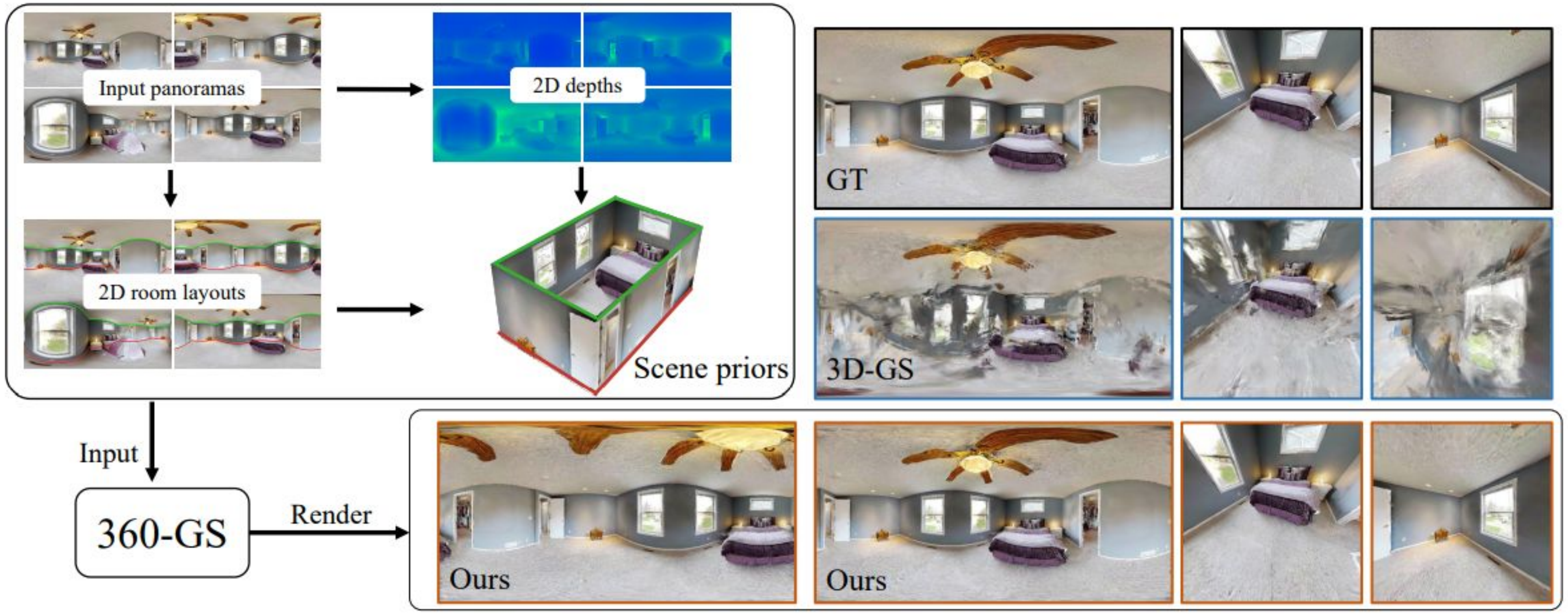
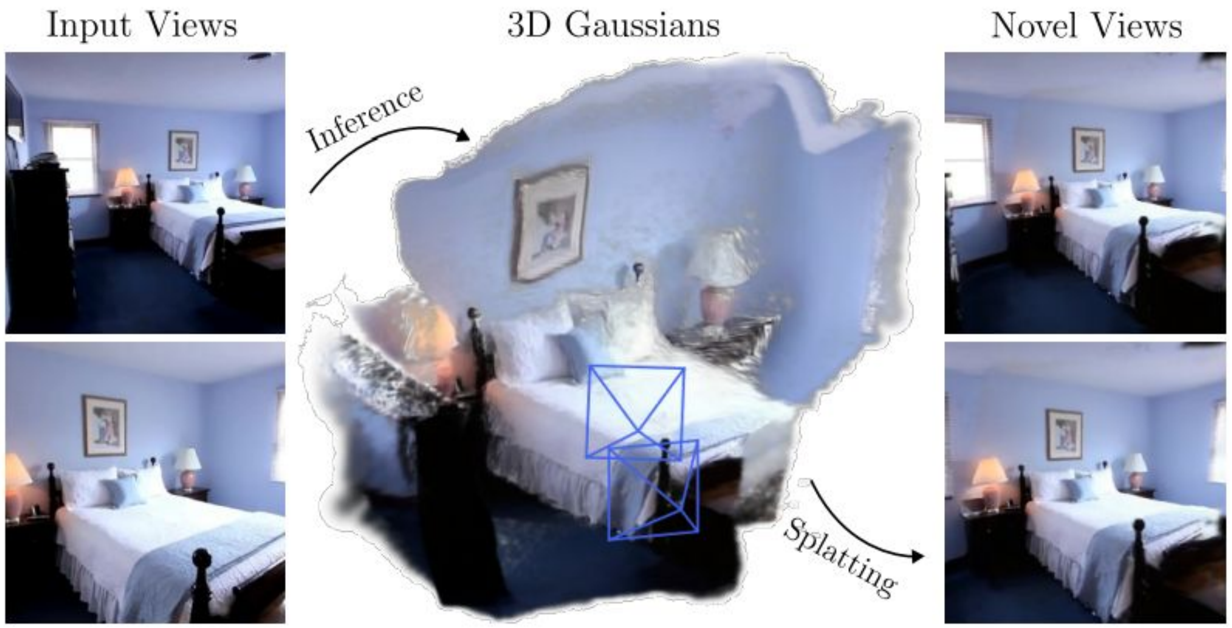


Bai, Jiayang, et al. "360-gs: Layout-guided panoramic gaussian splatting for indoor roaming." 2025 International Conference on 3D Vision (3DV). IEEE, 2025.

1. Introduction :: Feed-forward Splatting

- 3DGS needs to optimize
  - Not ideal and can be slow
  - Only works for many views (no sparse)
  - Use neural networks!



Charatan, David, et al. "pixelsplat: 3d gaussian splats from image pairs for scalable generalizable 3d reconstruction." Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2024.

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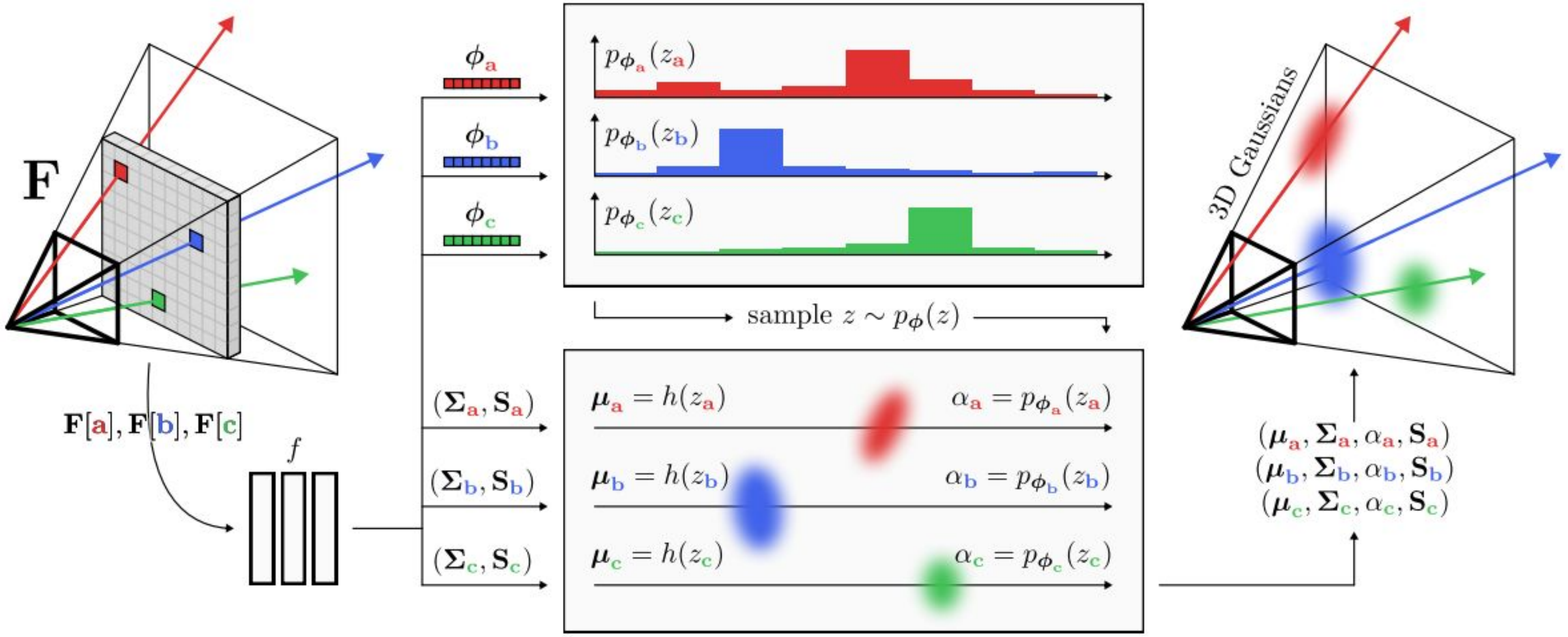

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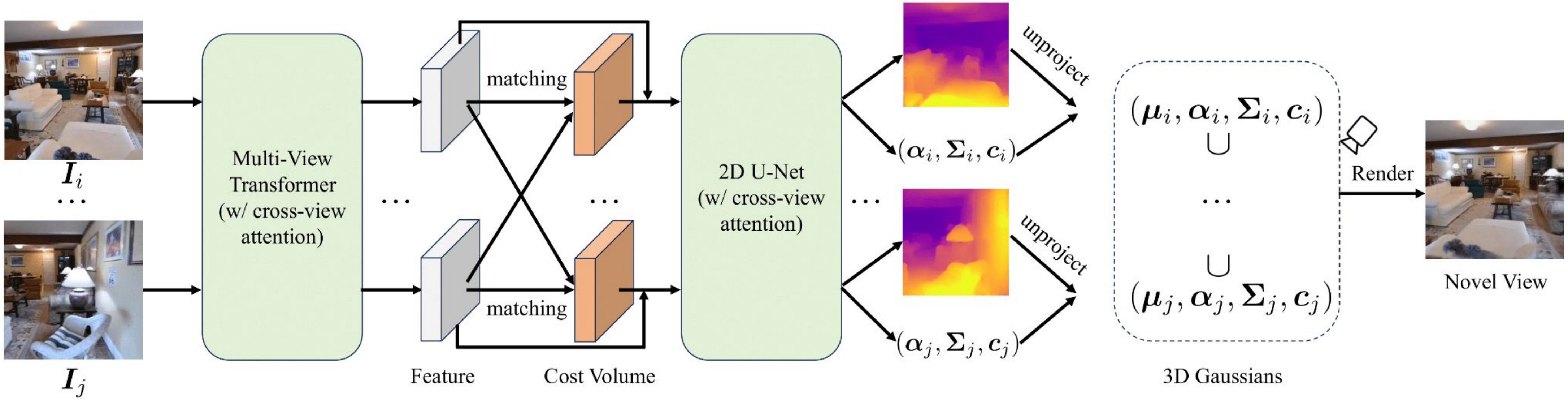
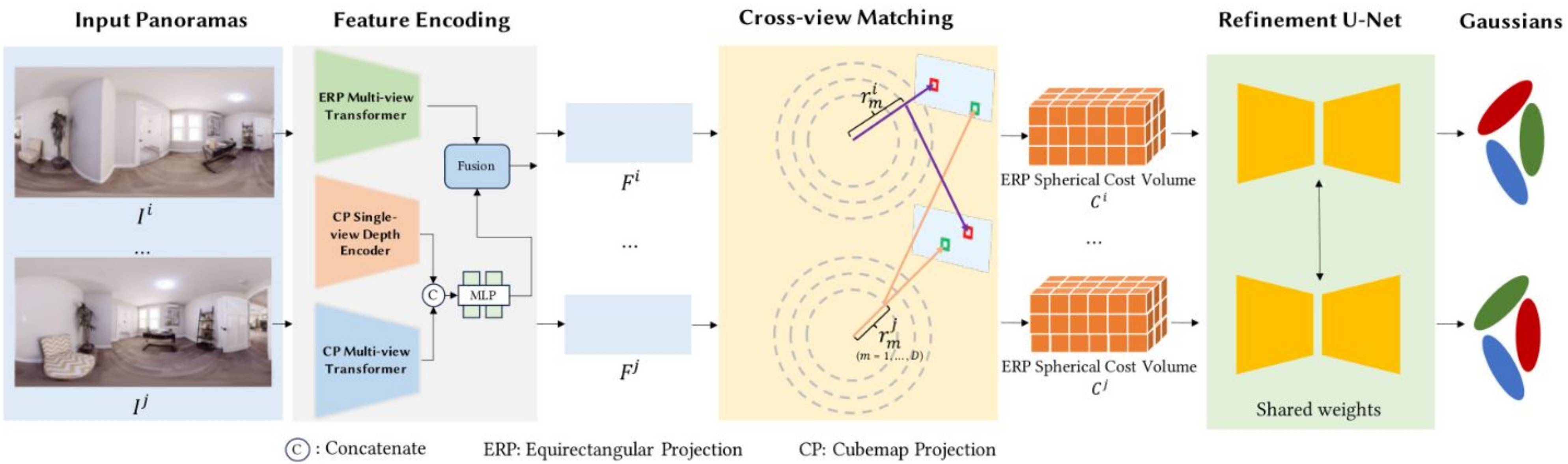


Chen, Yuedong, et al. "Mvsplat: Efficient 3d gaussian splatting from sparse multi-view images." European Conference on Computer Vision. Cham: Springer Nature Switzerland, 2024.

1. Introduction :: Splatter-360

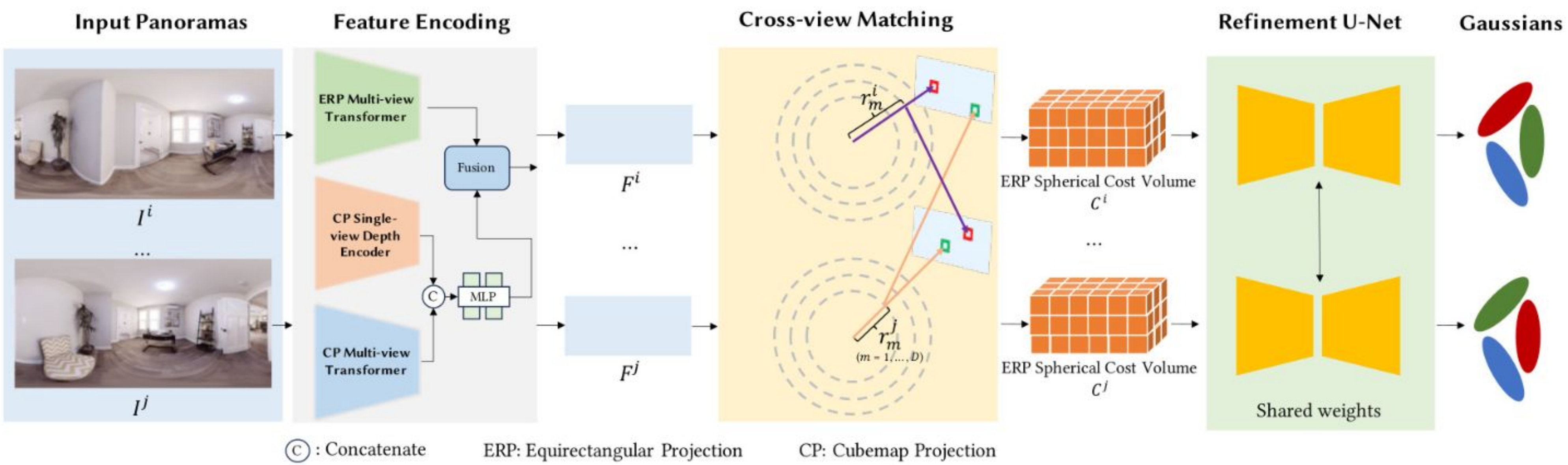
- What if we mixed the problems?
  - Wide-angle
  - Feed-forward



Chen, Zheng, et al. "Splatter-360: Generalizable 360 Gaussian Splatting for Wide-baseline Panoramic Images." Proceedings of the Computer Vision and Pattern Recognition Conference. 2025.

1. Introduction :: Splatter-360

- Objective
  - Perform feed-forward splatting with few-views
  - Equirectangular projection images
  - Present technique



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2. Splatter -360

2. Splatter-360 :: Intro

- Uses different representations
  - Strength of cube-map and equirectangular images
- Depth module

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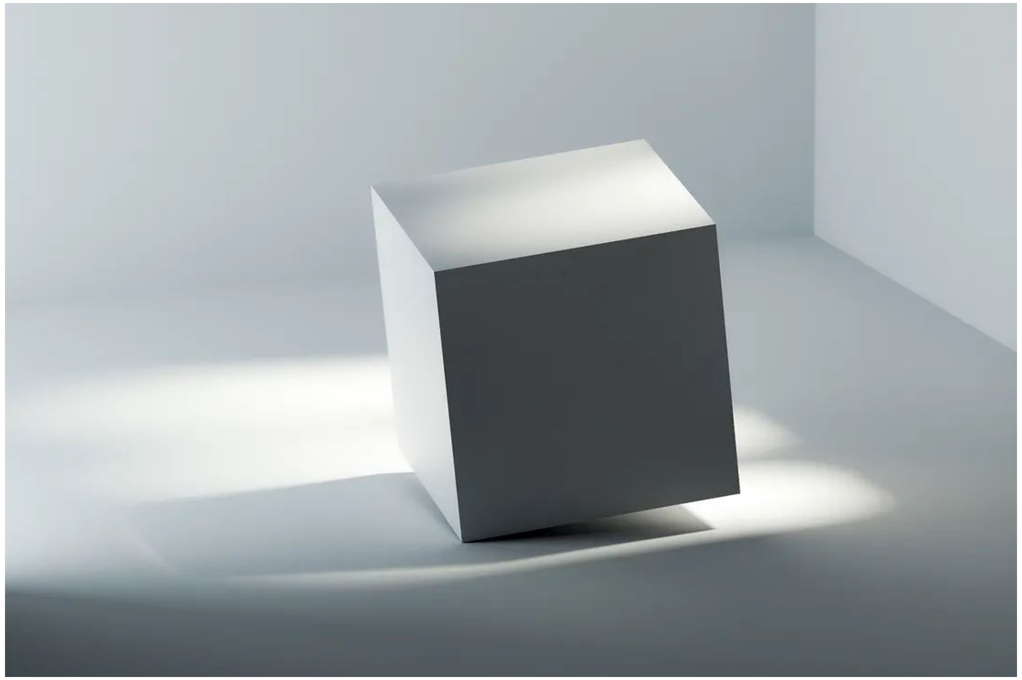

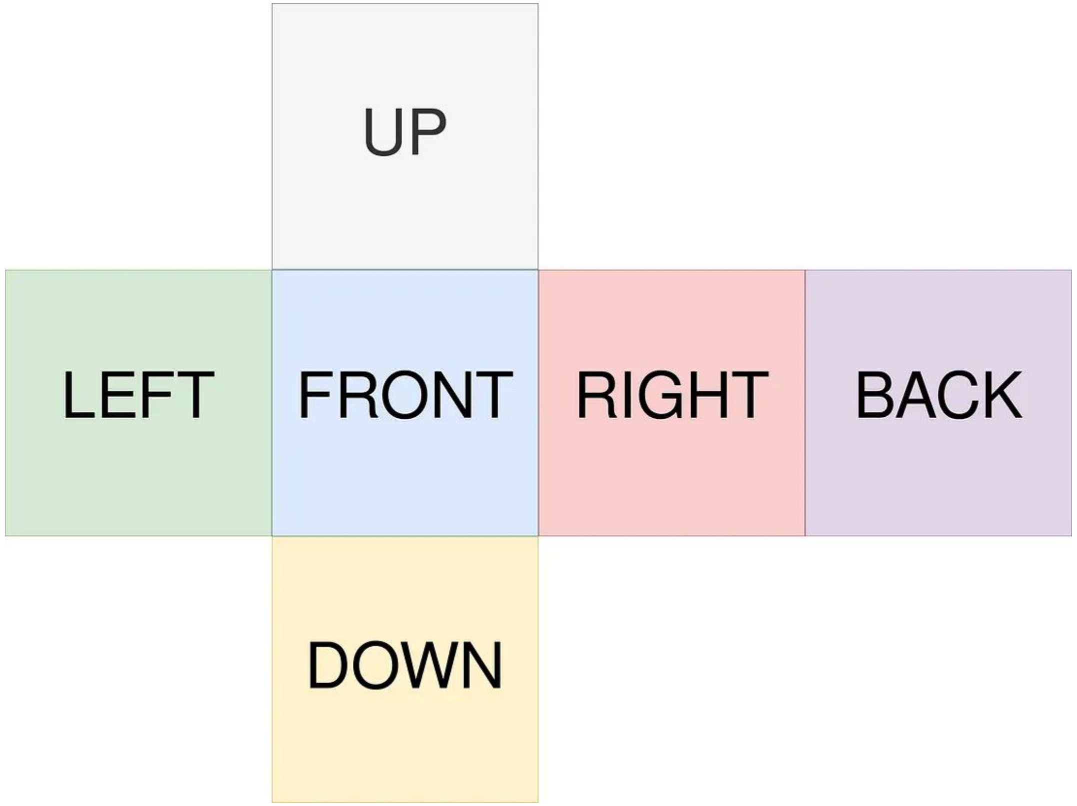

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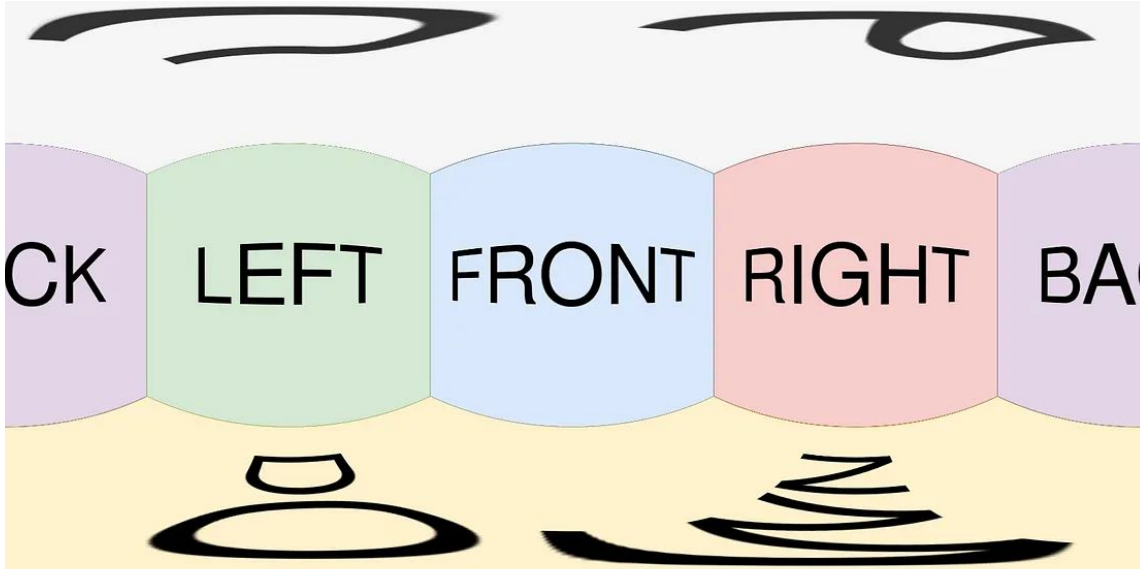

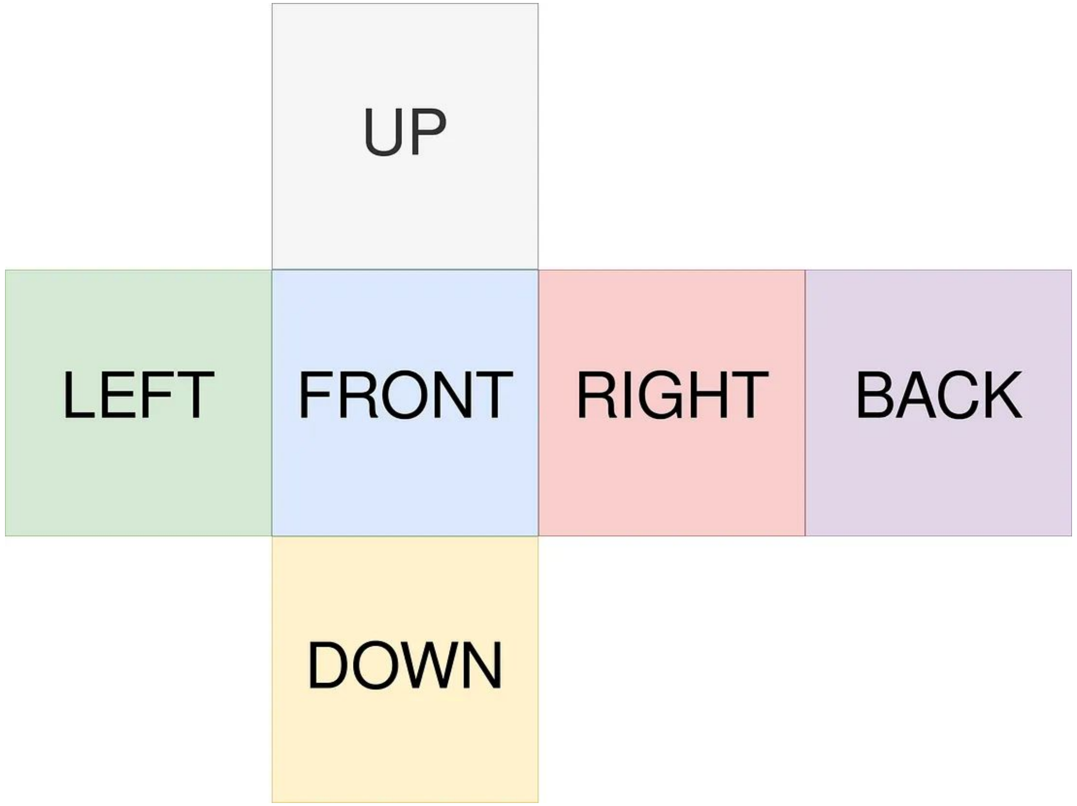

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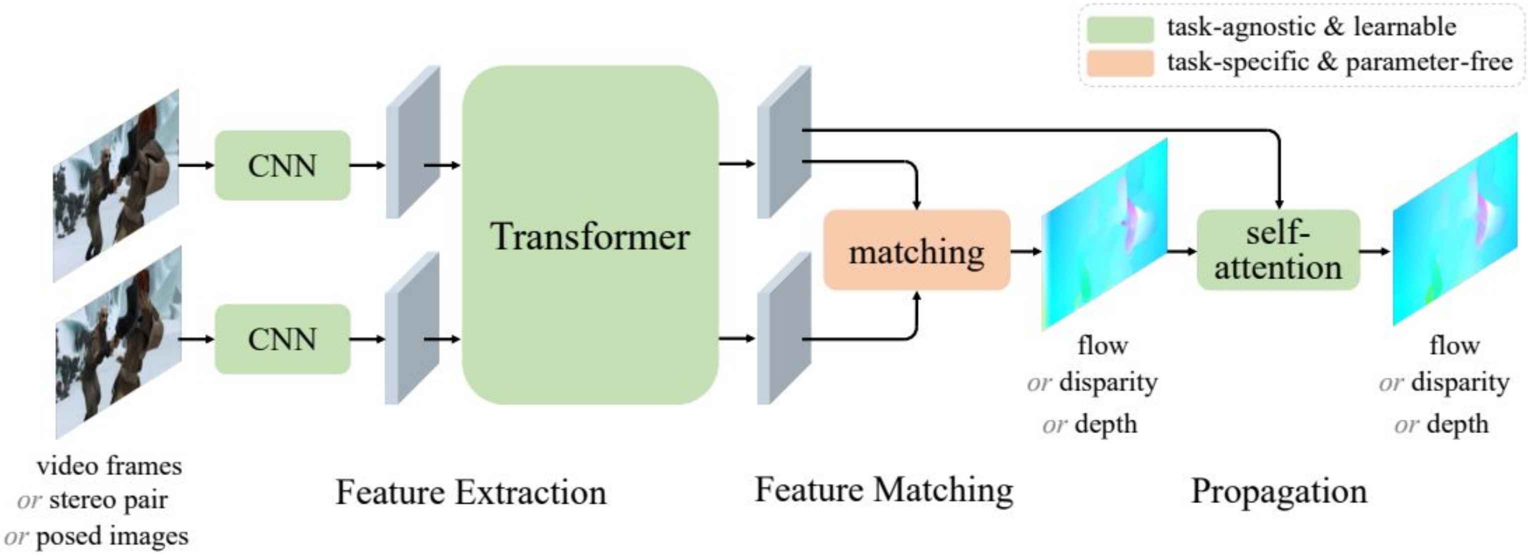
2. Splatter-360 :: Input

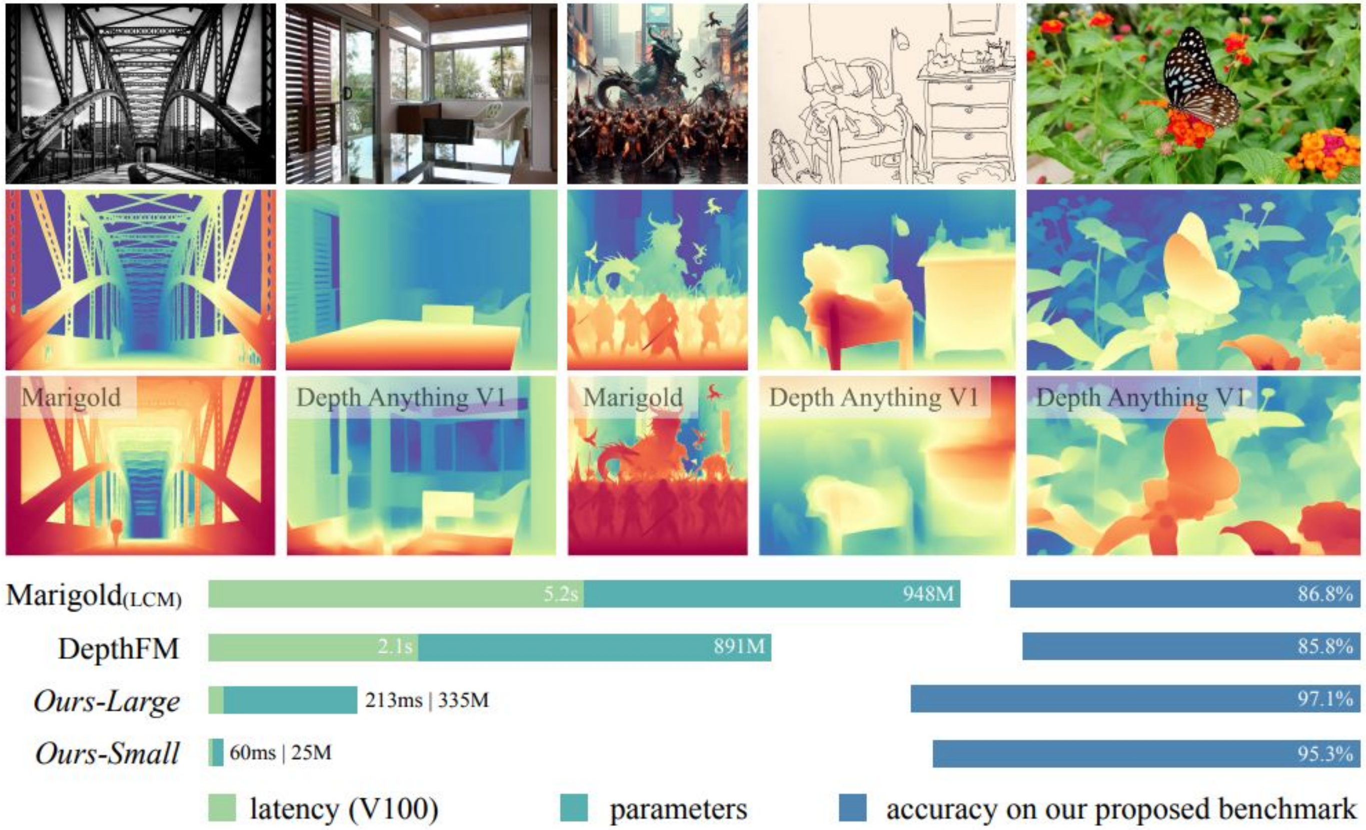
- Extract features F_ERP and F_CP
- Authors use Unimatch
    - Extract features from ERP and CP views



Chen, Zheng, et al. "Splatter-360: Generalizable 360 Gaussian Splatting for Wide-baseline Panoramic Images." Proceedings of the Computer Vision and Pattern Recognition Conference. 2025.

2. Splatter-360 :: Depth

- For cube-map, extract depth features



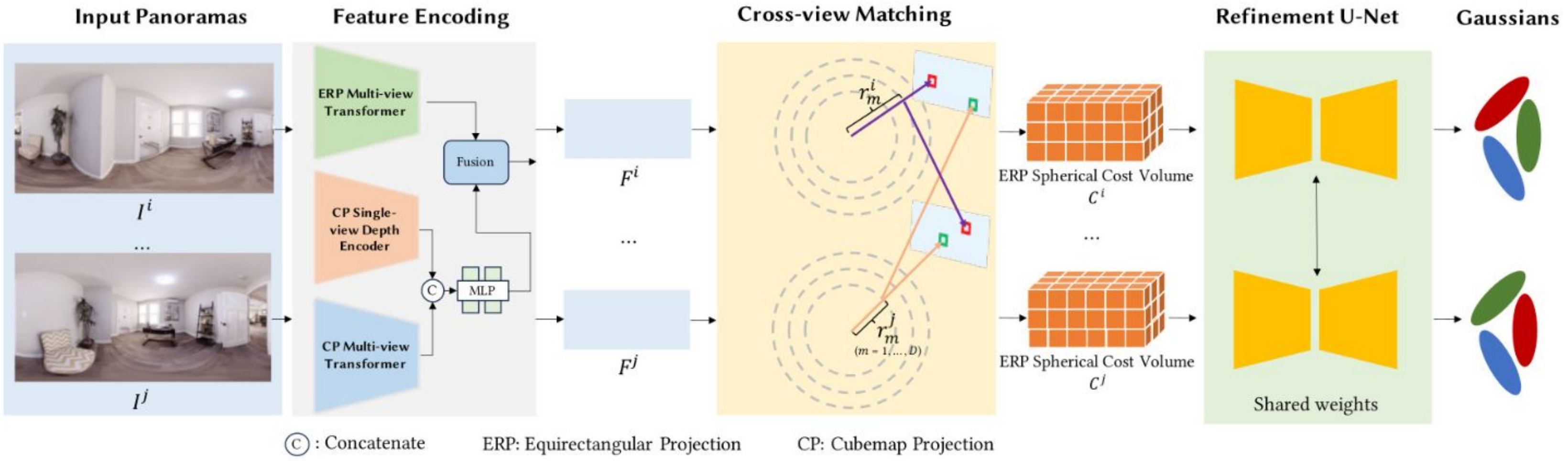
Yang, Lihe, et al. "Depth anything v2." Advances in Neural Information Processing Systems 37 (2024): 21875-21911.

2. Splatter-360 :: Features

- Use these features to perform feature encoding

$$F'_{C2E} = \mathcal{F}_1([F^{mono}_{C2E}, F_{C2E}])$$

$$F = \mathcal{F}_2(F'_{C2E}, F_{ERP})$$



2. Splatter-360 :: Cost Volume

- Construct cost volume
  - Depth map computation
  - Use cube-map
    - Can get behind the camera
    - Use Diff-pano approach

$$\begin{cases} \theta = (0.5 - \frac{u}{W}) \cdot 2\pi \\ \phi = (0.5 - \frac{v}{H}) \cdot \pi, \end{cases}$$

"A well-lit living space with wooden floors and a white ceiling, featuring an open doorway leading to a hallway. The room is furnished with a dining table and chairs. "

"A kitchen with white cabinets and black countertops. A well-lit room with white walls, wood floors, and a couch in the corner."

"A well-lit room with wooden floors, and a door that leads to a dining area. The room is decorated with a vase of flowers and features a ceiling with a light fixture."

"A well-maintained room with white walls and wooden floors. The room features a brown carpet, a bed, and a wooden dresser. A bedroom with an open door leading to the hallway."

$$\begin{cases} x_{cam} = r\cos(\phi) \cdot \sin(\theta) \\ y_{cam} = r\sin(\phi) \\ z_{cam} = r\cos(\phi) \cdot \cos(\theta), \end{cases}$$

Ye, Weicai, et al. "Diffpano: Scalable and consistent text to panorama generation with spherical epipolar-aware diffusion." Advances in Neural Information Processing Systems 37 (2024): 1304-1332.

2. Splatter-360 :: Cost Volume

- Construct the cost volume
  - You have source points (i) and target (j)
  - Use these to get the corresponding points in the camera
- Given a feature image F_i, compute distance with target F_(j->i)
  - Compute distance
  - Concatenate depths distance

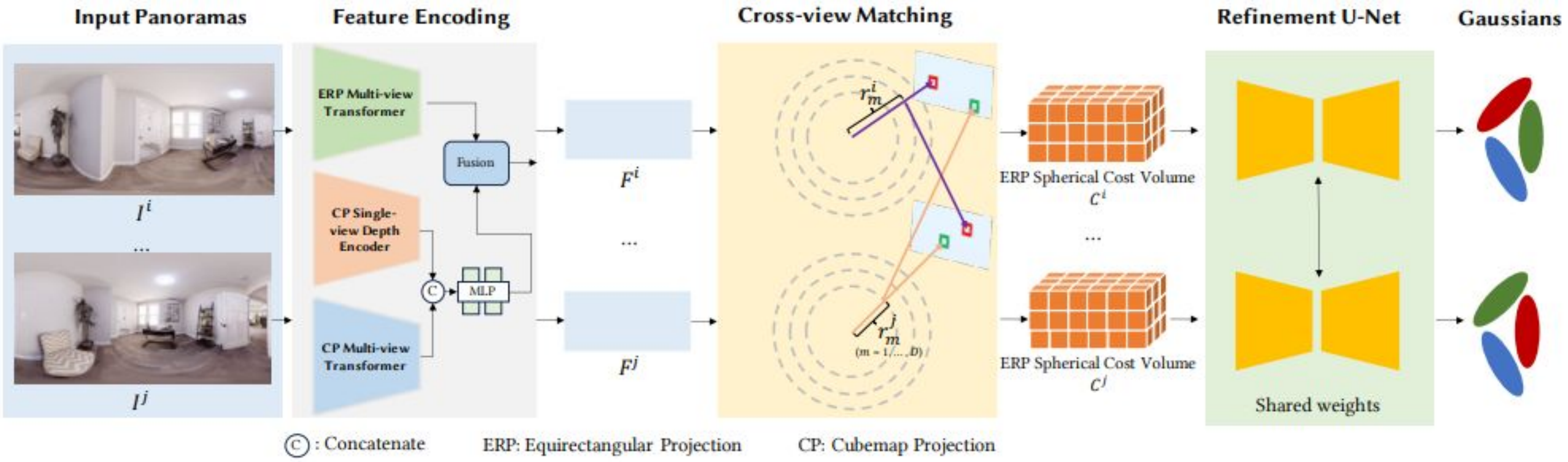
$$\boldsymbol{p}^{j}_{camera} = W^{i \to j} \boldsymbol{p}^{i}_{camera}$$

$$\boldsymbol{C}^{i}_{r_m} = \frac{\boldsymbol{F}^{i} \cdot \boldsymbol{F}^{j \to i}_{r_m}}{\sqrt{C}} \in \mathbb{R}^{H \times W}, \quad m = 1, 2, \cdots, D,$$

$$\boldsymbol{C}^{i} = [\boldsymbol{C}^{i}_{r_1}, \boldsymbol{C}^{i}_{r_2}, \cdots, \boldsymbol{C}^{i}_{r_D}] \in \mathbb{R}^{H \times W \times D}$$

2. Splatter-360 :: Cost Volume

- Use U-Net to refine cost volume
  - MVSplat
  - Finally, use softmax to compute final depth
  - Compute per-depth gaussians
    - Train as usual



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3. RESULTS

3. Results

- Used HM3D and Replica
- Compared with some techniques
  - PanoGRF
  - HiSplat
  - DepthSplat
  - MVSplat
- For various settings

3. Results

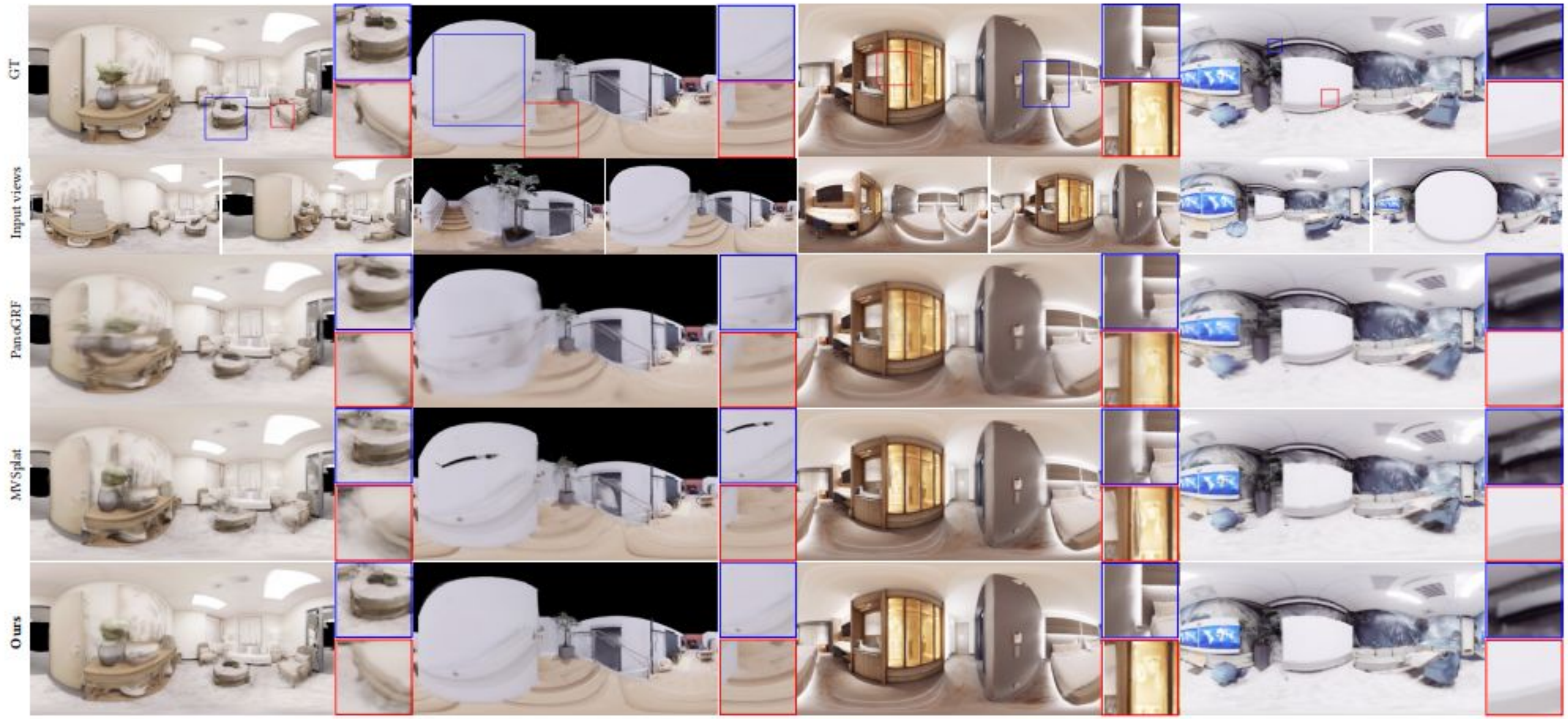

Figure 2. Qualitative comparison between our Splatter-360 and PanoGRF, MVSplat on the Replica dataset. Regions with notable differences are highlighted using red and blue rectangles. Please zoom in for a clearer view.

3. Results

Figure 3. Qualitative comparison between our Splatter-360 and PanoGRF, MVSplat on the HM3D dataset. Regions with notable differences are highlighted using red and blue rectangles. Please zoom in for a clearer view.

3. Results

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Table 1. Quantitative comparison with baseline methods on the HM3D and Replica datasets. † indicates models that were trained by us on the panoramic dataset, whereas for all other methods, we used the pre-trained models provided by the original authors.

	HM3D [27]			Replica [32]		
Method	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓
HiSplat [35]	17.268	0.624	0.488	17.157	0.642	0.417
MVSplat [5]	17.574	0.636	0.441	18.005	0.631	0.512
DepthSplat [46]	20.224	0.695	0.383	19.369	0.732	0.334
PanoGRF [8]	25.631	0.813	0.268	27.920	0.892	0.171
MVSplat† [5]	27.179	0.851	0.176	28.399	0.908	0.115
Splatter-360†	**28.293**	**0.875**	**0.155**	**29.888**	**0.924**	**0.097**

3. Results

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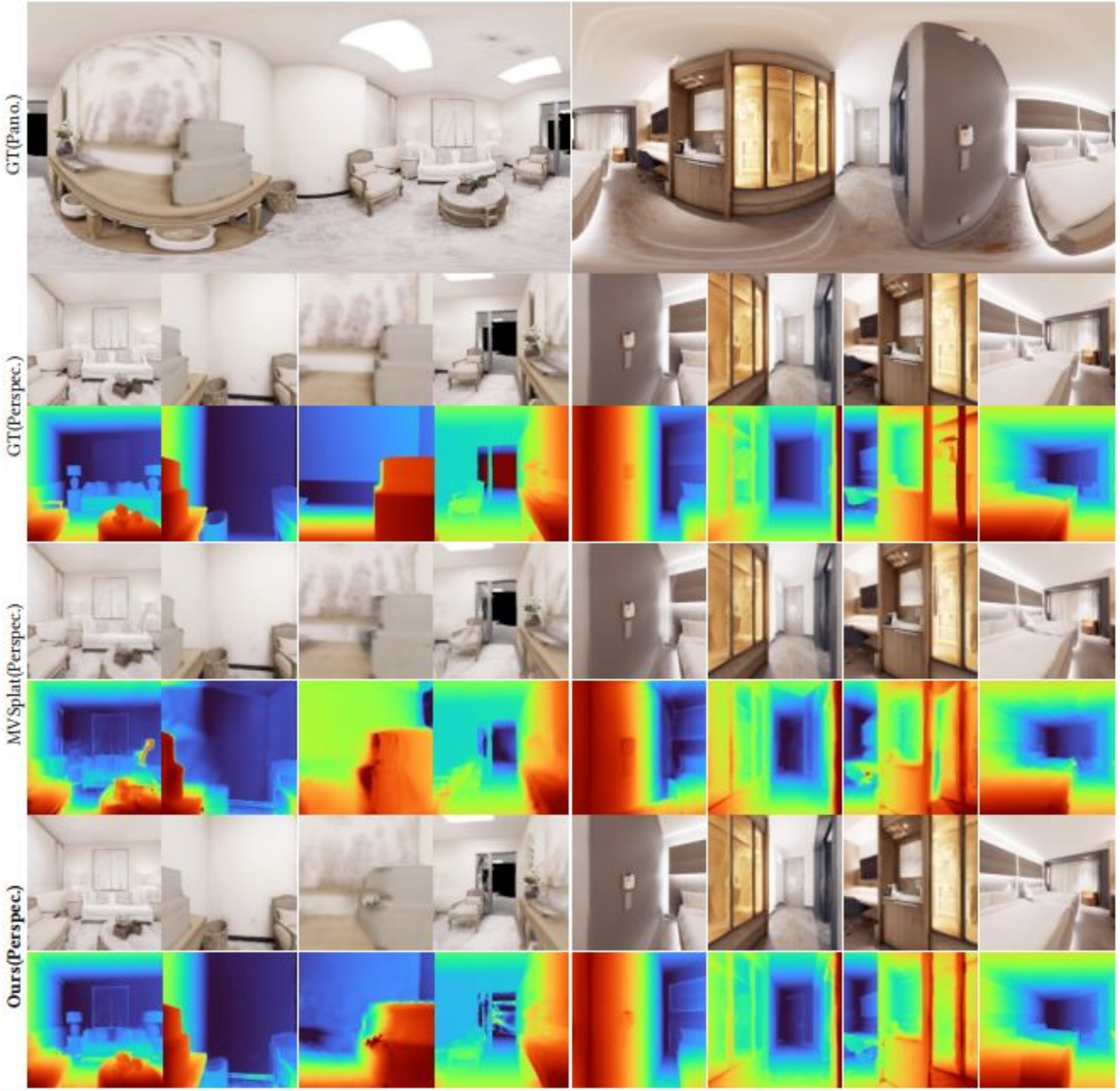

Figure 4. Novel view depth comparison between Splatter-360 and PanoGRF on the Replica dataset. “Pano.” denotes panoramic view and “Perspec.” denotes perspective view.

3. Results

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Table 2. Estimated depth comparison between MVSplat and Splatter-360 on the Replica and HM3D datasets.

Dataset	Metric	MVSplat	Splatter-360
Replica [32]	Abs Diff↓	0.132	**0.102**
	Abs Rel↓	0.088	**0.063**
	RMSE↓	0.247	**0.197**
	$\delta < 1.25$↑	89.913	**94.572**
HM3D [27]	Abs Diff↓	0.130	**0.106**
	Abs Rel↓	0.094	**0.076**
	RMSE↓	0.271	**0.223**
	$\delta < 1.25$↑	90.469	**93.851**

3. Results

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Table 3. Ablation studies were conducted on the HM3D and Replica datasets. For simplicity, we use the following abbreviations: 'SCV' for spherical cost volume and 'CVA' for cross-view attention.

Ablated module	Replica [32] PSNR↑	Replica [32] SSIM↑	Replica [32] LPIPS↓	HM3D [27] PSNR↑	HM3D [27] SSIM↑	HM3D [27] LPIPS↓
× SCV	23.850	0.818	0.210	25.224	0.802	0.223
× CVA	28.217	0.905	0.124	26.918	0.851	0.182
× ERP	26.985	0.887	0.142	25.905	0.827	0.202
× CP	28.673	0.909	0.117	27.277	0.857	0.174
× Mono Feat.	28.654	0.911	0.116	27.380	0.858	0.173
Full	**29.121**	**0.914**	**0.111**	**27.487**	**0.860**	**0.171**

3. Results

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Table 4. Quantitative comparison with three context views between MVSplat and Splatter-360 on the Replica and HM3D datasets.

Dataset	Metric	MVSplat	Splatter-360
Replica [32]	PSNR↑	**29.121**	29.109
	SSIM↑	0.908	**0.913**
	LPIPS↓	0.123	**0.116**
	Abs Diff↓	0.125	**0.103**
	Abs Rel↓	0.078	**0.060**
	RMSE↓	0.233	**0.193**
	$\delta < 1.25$↑	90.771	**94.367**
HM3D [27]	PSNR↑	27.858	**27.905**
	SSIM↑	0.861	**0.868**
	LPIPS↓	0.174	**0.168**
	Abs Diff↓	0.118	**0.095**
	Abs Rel↓	0.083	**0.067**
	RMSE↓	0.251	**0.209**
	$\delta < 1.25$↑	91.684	**94.545**

3. Results

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Table 5. Quantitative comparison under a narrow baseline between MVSplat and Splatter-360 on the Replica and HM3D datasets.

Dataset	Metric	MVSplat	Splatter-360
Replica [32]	PSNR↑	32.521	**33.282**
	SSIM↑	0.951	**0.957**
	LPIPS↓	0.064	**0.058**
	Abs Diff↓	0.109	**0.090**
	Abs Rel↓	0.057	**0.048**
	RMSE↓	0.214	**0.171**
	$\delta < 1.25$↑	94.257	**96.645**
HM3D [27]	PSNR↑	30.851	**31.493**
	SSIM↑	0.915	**0.925**
	LPIPS↓	0.109	**0.101**
	Abs Diff↓	0.102	**0.092**
	Abs Rel↓	0.060	**0.058**
	RMSE↓	0.228	**0.189**
	$\delta < 1.25$↑	94.802	**96.031**

3. Results

- Trained on a cluster of GPUs V100
  - Can’t train
- Shared a model to test
  - However, need to download 11 Gb Replica dataset

4. Conclusion

4. Conclusion

- Review:
    - Great idea and technique!
    - But paper could be more clearly written (loss function not specified)
    - PSNR difference is small
- But great work!!

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