DDNeRF: Depth Distribution Neural Radiance Fields

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Overview

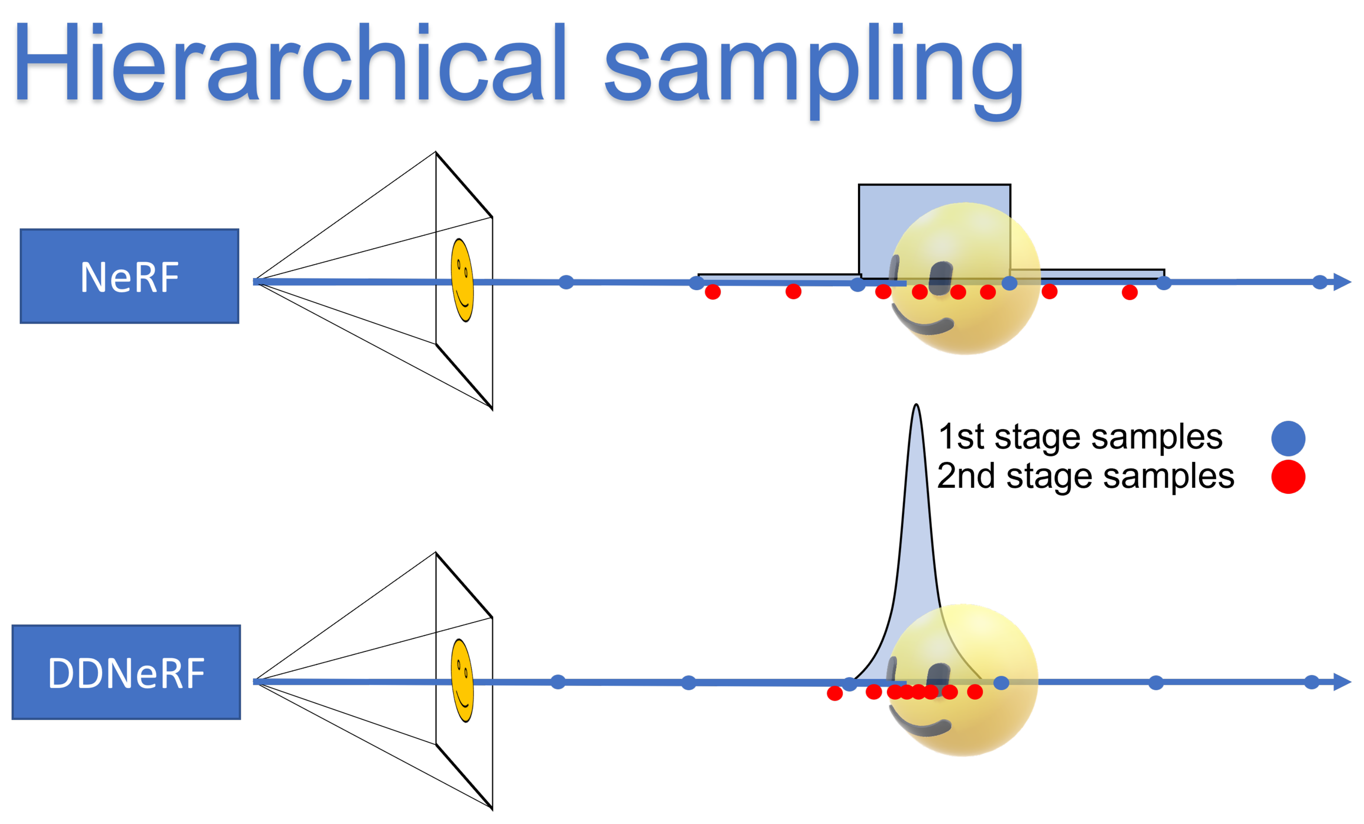
Neural radiance fields (NeRF) models, can represent high-quality scenes but still suffers from two main drawbacks:

1. **The training process is computationally very expensive.**
2. **Struggles with real life 360° complex scenes.**

We propose **DDNeRF - depth distribution neural radiance fields**:

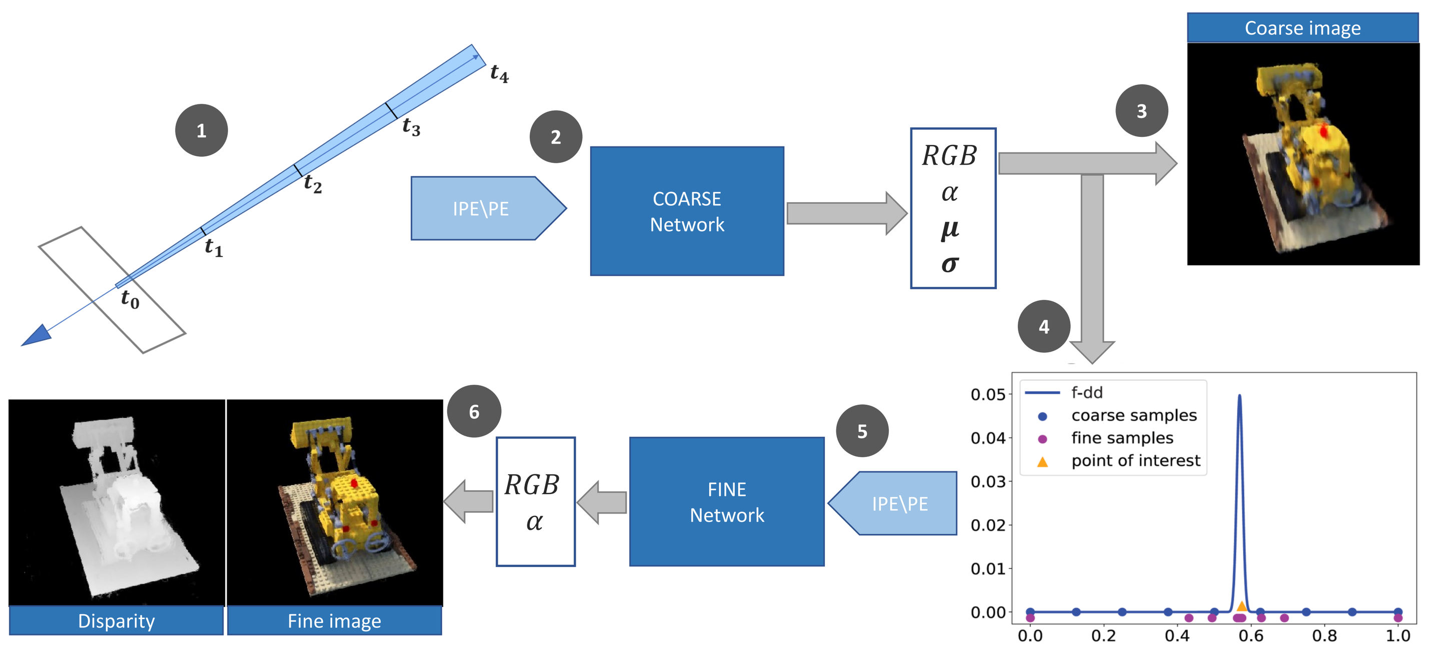
New method that significantly increases sampling efficiency, accelerates the training process and improves output quality.

Our method represents the PDF in the Hierarchical Sampling as a **mixture of Truncated Gaussian distributions.** This allows using fewer samples during training and inference while achieving better output quality.

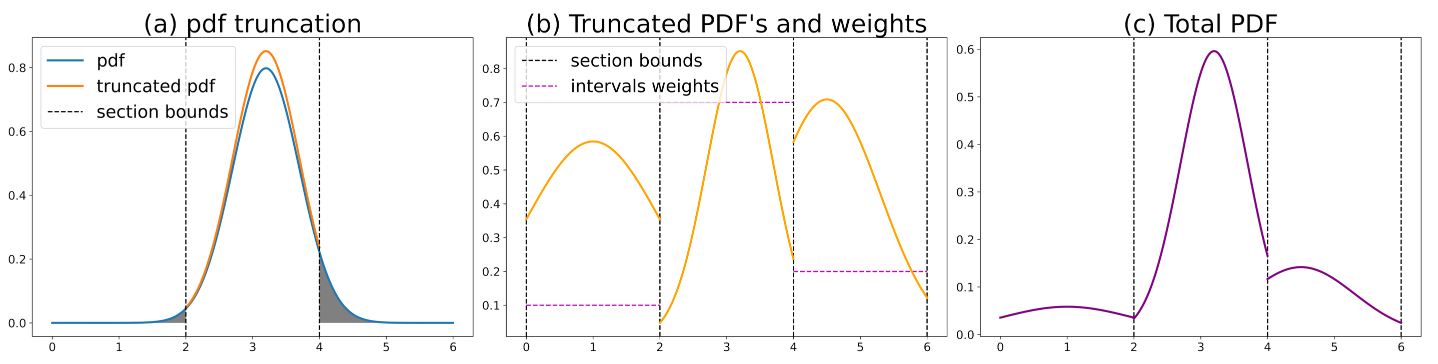


Method

DDNeRF Full Pipe:



Distribution Estimation:



$$f_{dd}(t) = h_i^c \cdot f_i'(t) \quad \text{for} \quad t \in [t_i^c, t_{i+1}^c] \qquad (1)$$

where h_i^c and f_i' are the weight and the truncated Gaussian of interval i, respectively.

Training Process

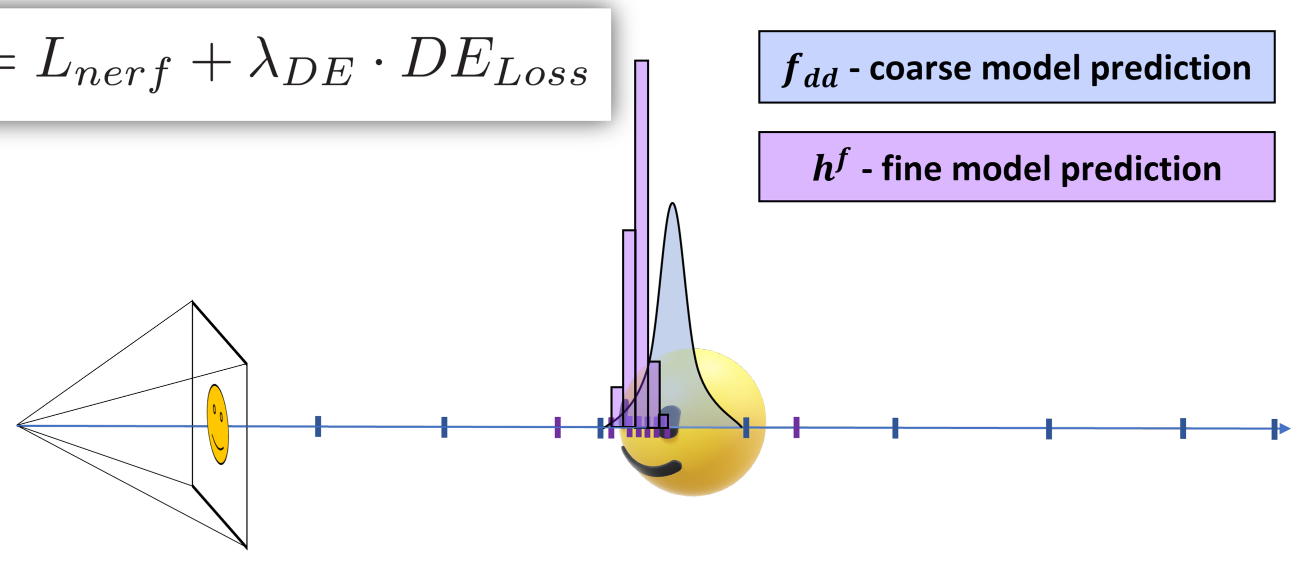
Loss Function:

$$DE_{Loss} = KL(f_{dd}, h^f) + \text{regularization}$$

$$L = L_{nerf} + \lambda_{DE} \cdot DE_{Loss}$$

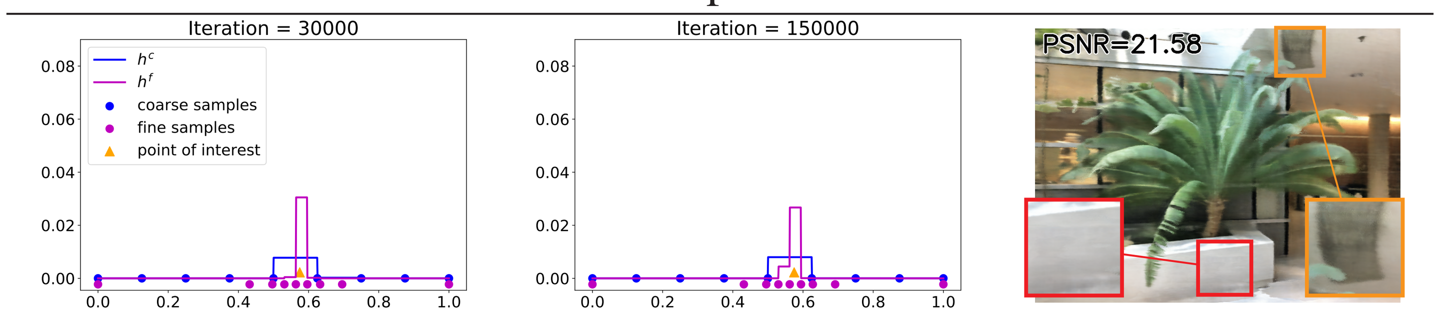
f_{dd} - coarse model prediction

h^f - fine model prediction

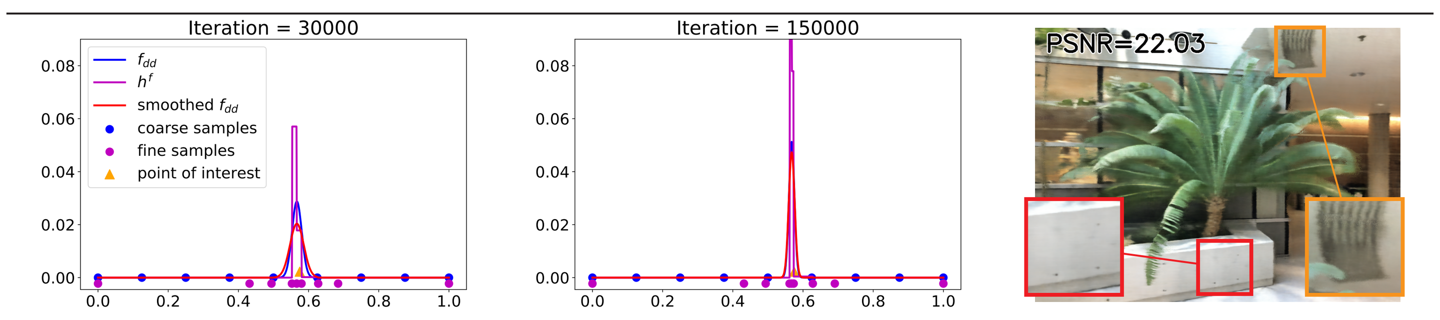


Training Process:

MipNeRF



DDNeRF



Quantitative Results

Per Domain Results:

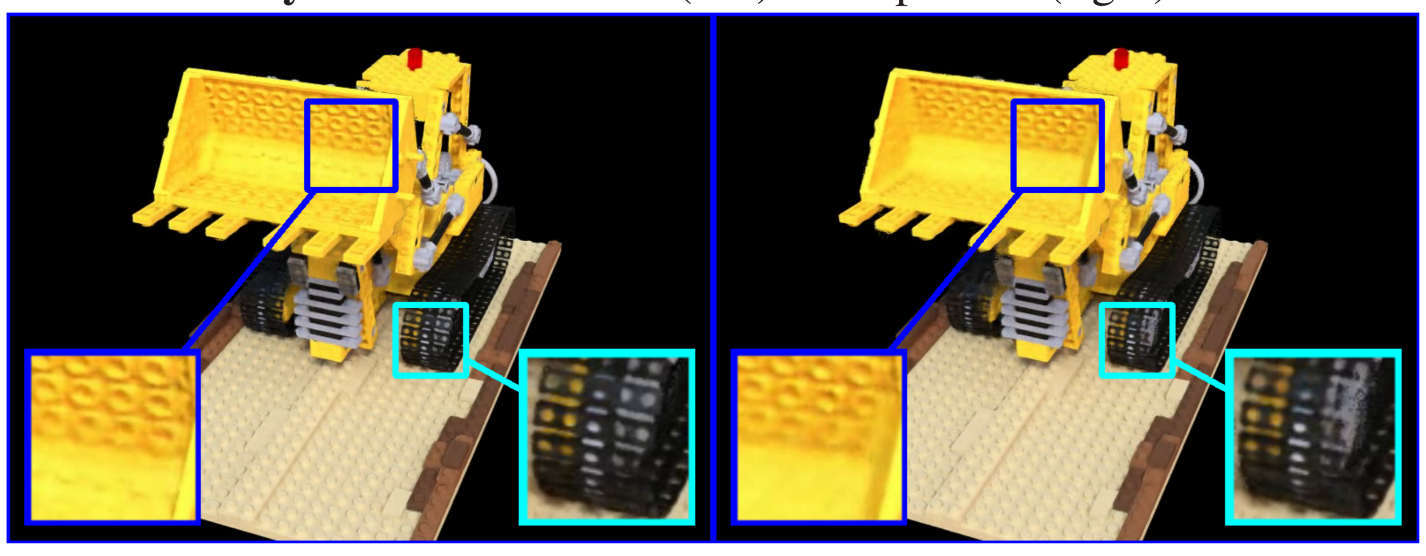
Domain	Samples	Model	PSNR↑	SSIM↑	LPIPS↓
Forward Facing	16	Mip-NeRF	23.33	0.738	0.289
		DDNeRF	**23.61**	**0.759**	**0.262**
	32	Mip-NeRF	24.32	0.783	0.227
		DDNeRF	**24.39**	**0.789**	**0.219**
Synthetic	16	Mip-NeRF	27.10	0.904	0.100
		DDNeRF	**27.66**	**0.922**	**0.079**
	32	Mip-NeRF	29.46	0.940	0.050
		DDNeRF	**30.17**	**0.951**	**0.039**
360° Bounded	96	Mip-NeRF	20.80	0.563	0.488
		DDNeRF	**21.12**	**0.593**	**0.418**
360° Unbounded	96	NeRF++	21.81	0.625	0.447
		DDNeRF++	**21.82**	**0.633**	**0.417**

Computation-Quality Trade-Off:

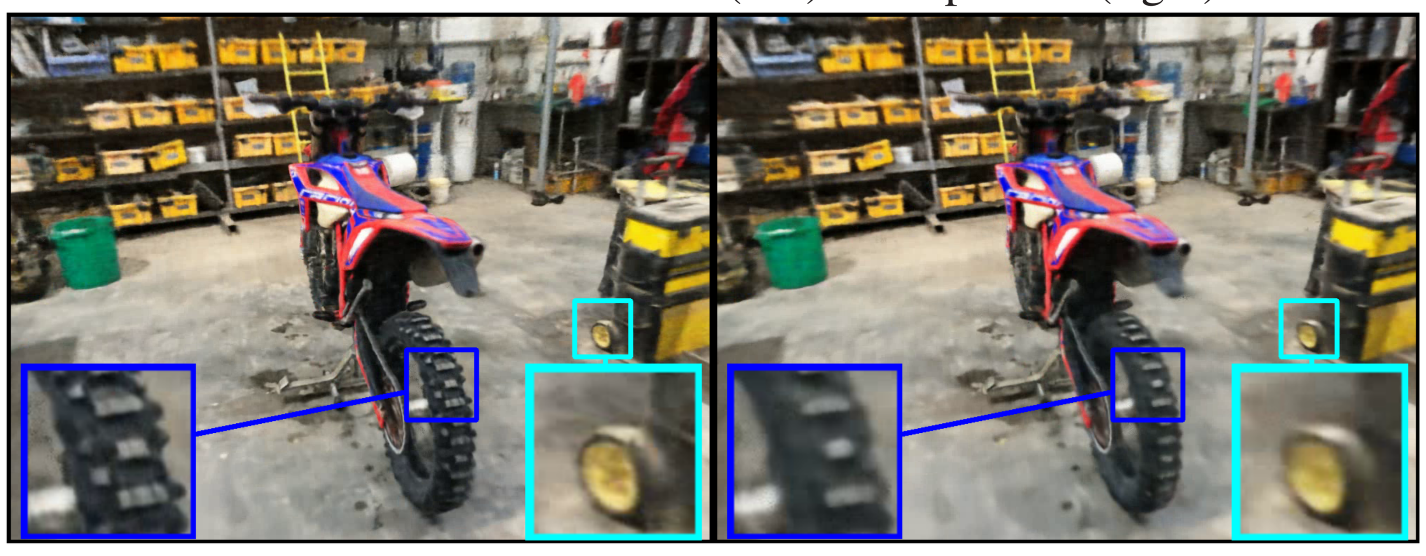
Model	Samples	Iters	PSNR↑	SSIM↑	LPIPS↓	Time	Render
Mip-NeRF	96	300k	20.8	0.563	0.488	11.8H	20.91s
DDNeRF	32	300k	20.84	0.577	0.453	5.5H	**7.05s**
DDNeRF	96	80k	20.37	0.556	0.458	3.6H	21.37s
DDNeRF	96	100k	20.63	0.566	0.447	4.5H	21.37s
DDNeRF	96	140k	20.89	0.581	0.429	6.3H	21.37s
DDNeRF	96	300k	**21.12**	**0.593**	**0.418**	13.6H	21.37s

Qualitative Results

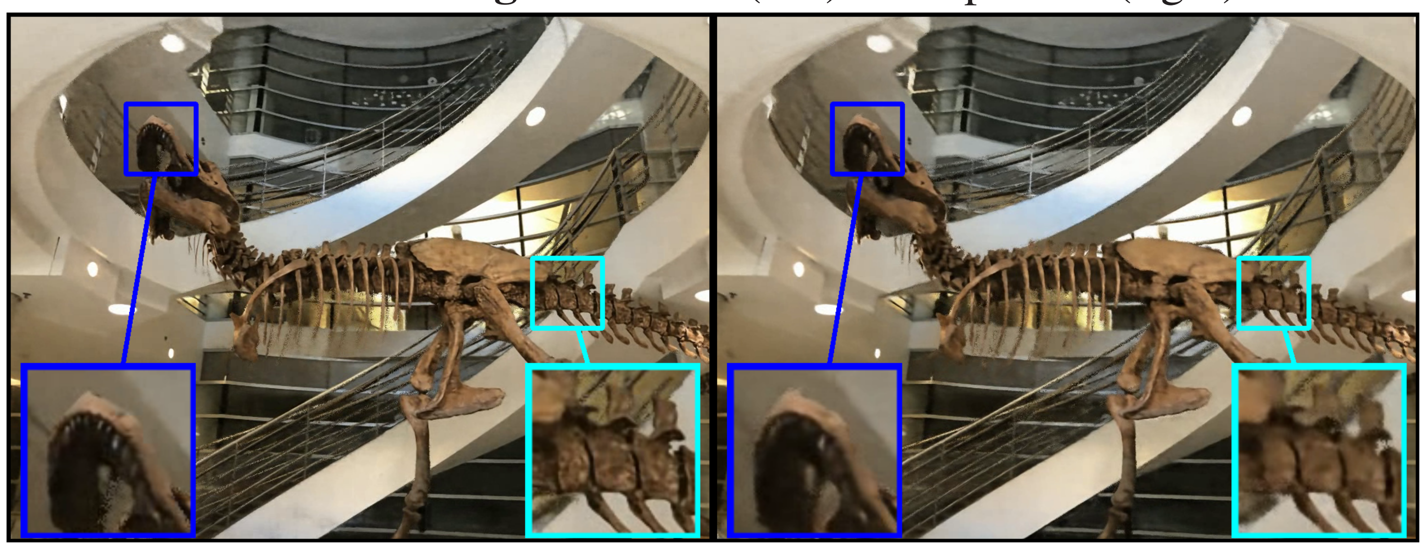
Synthetic: DDNeRF (left) vs MipNeRF (right)



360° **Bounded:** DDNeRF (left) vs MipNeRF (right)



Forward Facing: DDNeRF (left) vs MipNeRF (right)



360° **Unbounded:** DDNeRF++ (left) vs NeRF++ (right)