DReg-NeRF: Deep Registration for Neural Radiance Fields

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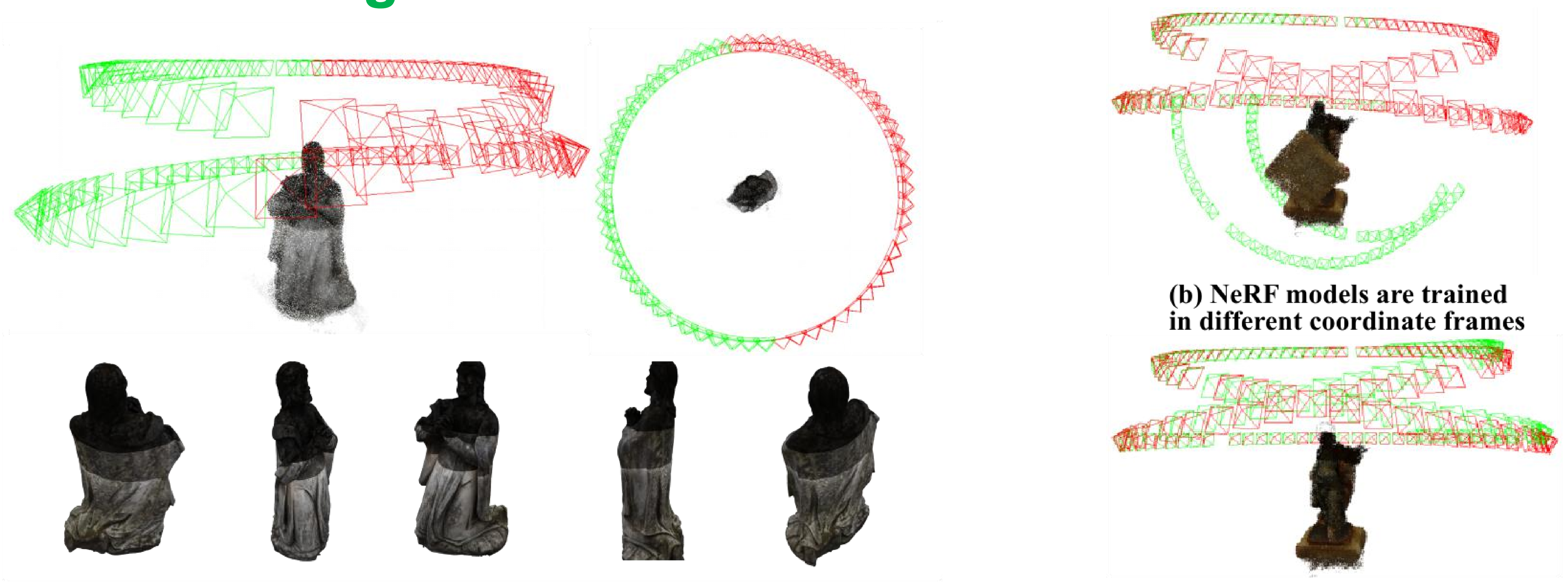
INTRODUCTION

Task Setting



(a) Objaverse

(b) NeRF models are trained in different coordinate frames

(c) DReg-NeRF aligns NeRF blocks into the same coordinate frame without accessing raw image data

Our method registers multiple NeRF blocks. (a) One of the collected objects from the Objaverse dataset. We render the images from a predefined camera trajectory to construct our training data. (b) NeRF models are trained in different coordinate frames. (c) Our method aligns NeRF blocks into the same coordinate frame without accessing raw image data.

Training Data Rendered from 3D Objects

APPROACH

Training Loss

✓ **Surface Field Loss** $\mathcal{L}_{\mathrm{sf}} = \frac{1}{N}\|\mathbf{S}([\widehat{\mathbf{X}}_{\mathrm{src}}, \widehat{\mathbf{X}}_{\mathrm{tgt}}]) + \mathbf{S}([\widetilde{\mathbf{X}}_{\mathrm{src}}, \widetilde{\mathbf{X}}_{\mathrm{tgt}}])\|_1$

Definition:

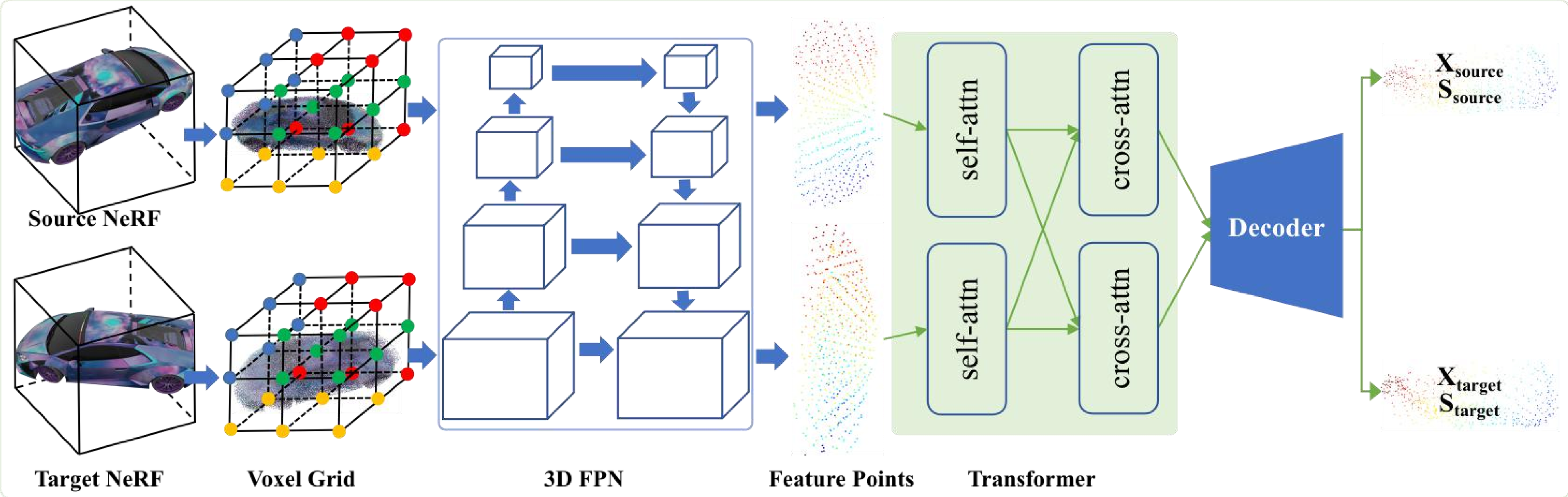
The surface field is the differential probability of the ray hitting a surface at a given point $\boldsymbol{X}$.

✓ **Confidence Loss** $\mathcal{L}_{\mathrm{conf}} = \mathrm{BCE}(\widehat{\mathbf{S}}_{\mathrm{src}}, \widetilde{\mathbf{S}}_{\mathrm{src}}) + \mathrm{BCE}(\widehat{\mathbf{S}}_{\mathrm{tgt}}, \widetilde{\mathbf{S}}_{\mathrm{tgt}})$

✓ **Correspondence Loss** $\mathcal{L}_{\mathrm{corr}} = \sum \rho(S\|T^*(\mathbf{x}_i) - \mathbf{y}_i\|; \eta, \gamma)$

✓ **Final Loss** $\mathcal{L}_{\mathrm{final}} = \mathcal{L}_{\mathrm{conf}} + \lambda_1\mathcal{L}_{\mathrm{sf}} + \lambda_2\mathcal{L}_{\mathrm{corr}} + \lambda_3\mathcal{L}_{\mathrm{feat}}$

Network Architecture



1) **Extract** the pairwise voxel grid and a binary mask from the source and target NeRF.
2) **Feed** the voxel grid and a binary mask into the 3D feature pyramid network to extract voxel features.
3) **Downsample** the extracted voxel grid features by their spherical neighborhood.
4) **Strengthen** the resulting source and target features features by a transformer, where a self-attention layer is used to enhance the intra-contextual relations, and a cross-attention layer is used to learn the inter-contextual relations.
5) **Decode** the features into correspondences and their corresponding confidence scores by a single-head attention layer.

RESULTS

Quantitative Results

		Food 5648	Chair 4b05	Chair 4659	Chair 3f2d	Cone 37b5	Figurine 260d	Figurine 0a5b	Figurine 09f0	Banana 3a07	Banana 2373	Banana 0a07
ΔR	FGR [45]	178.34	50.50	28.54	81.31	104.52	89.13	26.35	138.00	12.17	6.92	2.86
	REGTR [42]	169.07	150.38	92.80	98.67	62.50	111.80	106.12	176.48	136.02	178.36	173.96
	Ours_{df}	77.48	160.13	157.21	22.91	108.09	121.32	10.53	95.89	95.43	**3.49**	6.96
	Ours	**6.01**	**6.53**	**17.74**	**18.88**	**18.79**	**2.11**	**7.62**	**8.25**	**15.55**	10.95	**1.36**
Δt	FGR [45]	17.44	**2.27**	**7.10**	8.65	30.49	19.25	10.93	35.22	8.50	1.53	1.36
	REGTR [42]	30.72	15.41	24.97	60.53	84.20	62.07	35.48	42.10	10.75	50.40	13.17
	Ours_{df}	15.52	7.32	11.72	**2.29**	21.70	33.61	**1.95**	21.40	13.14	4.28	**0.50**
	Ours	**1.78**	4.13	8.74	5.07	**3.06**	**3.54**	10.68	**3.18**	**0.46**	**1.00**	1.22

		Fireplug 06d5	Fireplug 0063	Fireplug 0152	Shoe 18c3	Shoe 1627	Shoe 0bf9	Shoe 022c	Teddy 1b47	Elephant 183a	Elephant 1608	Elephant 1a39
ΔR	FGR [45]	**6.19**	20.32	7.50	10.23	178.14	71.55	50.28	8.05	7.65	21.37	30.97
	REGTR [42]	156.92	99.60	**4.04**	**2.55**	175.21	97.92	154.91	149.17	177.15	172.28	102.62
	Ours_{df}	156.17	45.76	12.34	14.69	131.66	158.66	6.84	**6.32**	**6.97**	**3.92**	126.94
	Ours	7.96	**17.43**	4.86	6.06	**12.95**	**6.48**	**2.93**	11.44	8.00	11.13	**13.84**
Δt	FGR [45]	5.83	**0.83**	1.17	**0.04**	**4.99**	8.82	35.47	1.11	4.51	14.08	11.03
	REGTR [42]	68.71	38.74	2.13	3.53	43.40	61.37	102.00	42.84	52.26	66.15	34.54
	Ours_{df}	10.54	5.32	2.60	4.66	28.63	24.82	4.40	2.20	**4.26**	**1.40**	33.57
	Ours	**1.58**	5.08	**0.96**	2.08	12.80	**1.81**	**0.65**	**1.06**	8.97	6.17	**7.80**

Qualitative Results

CHECK OUT OUR PROJECT PAGE FOR MORE DETAILS!

https://aibluefisher.github.io/DReg-NeRF