

LightNeuS: Neural Surface Reconstruction in Endoscopy Using Illumination Decline

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Introduction

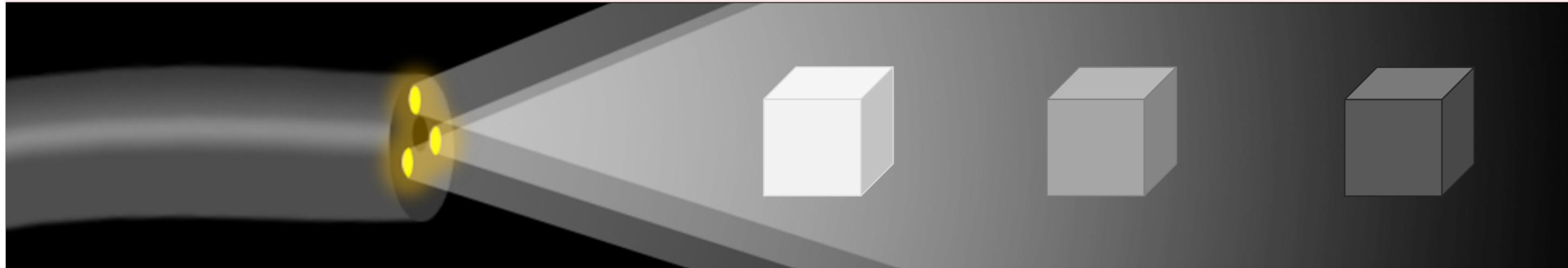
Goal:

3D reconstruction from monocular endoscopes.

Key insights:

❖ Signed distance function (SDF) is watertight.

❖ Illumination declines with distance.



NeuS

We build on Neural implicit Surfaces (NeuS) [1]

❖ NeuS fails with illumination changes.

❖ Endoscopes can only capture few viewing directions.

LightNeuS

❖ Exploit the relation of brightness \mathcal{I} and depth t

$$\mathcal{I}(\mathbf{x}) = \left(\frac{L_e}{t^2} \text{BRDF}(\mathbf{x}, \mathbf{d}) \cos(\theta) g \right)^{1/\gamma}$$

❖ Introduce a calibrated photometric model of the endoscope's camera and light source.

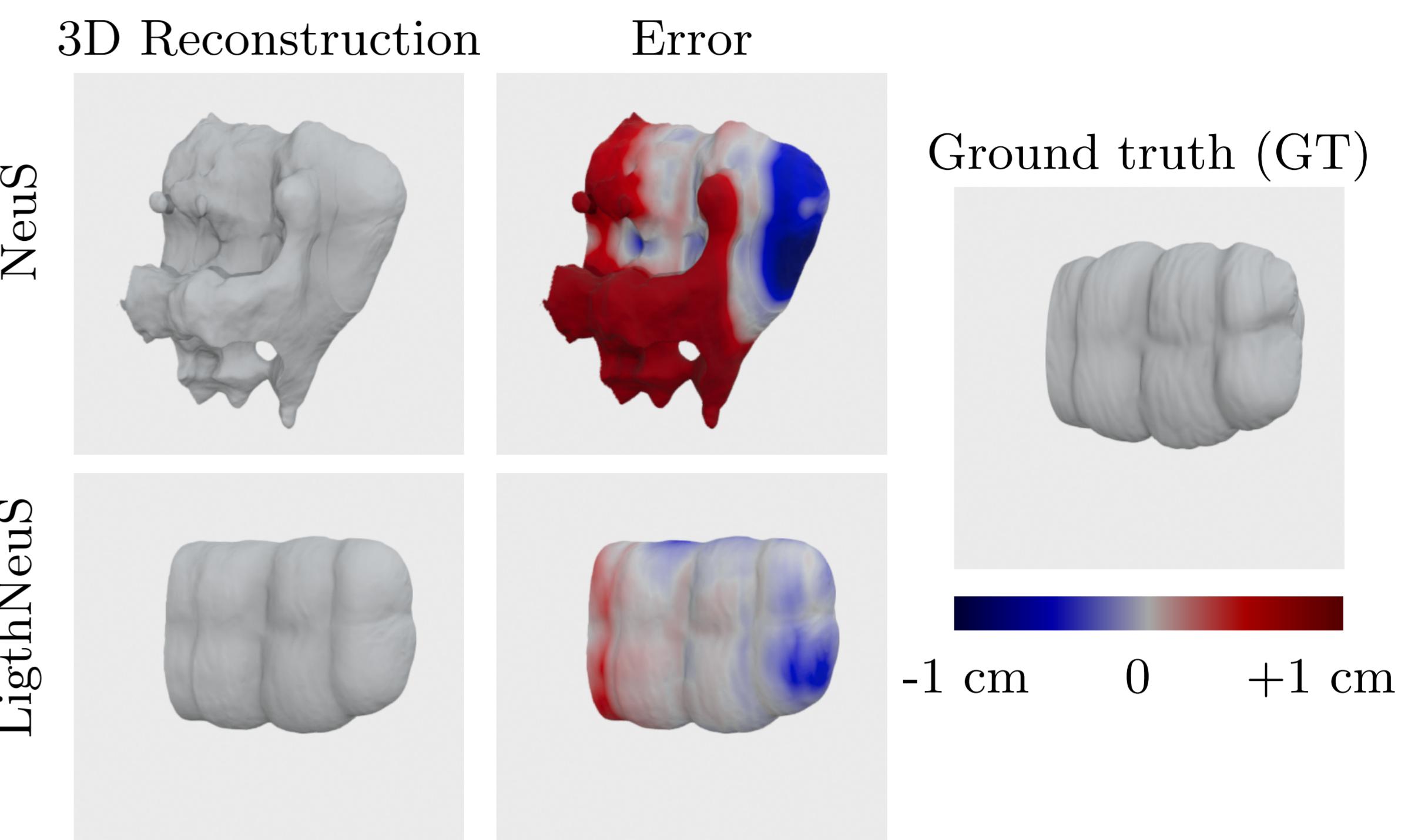
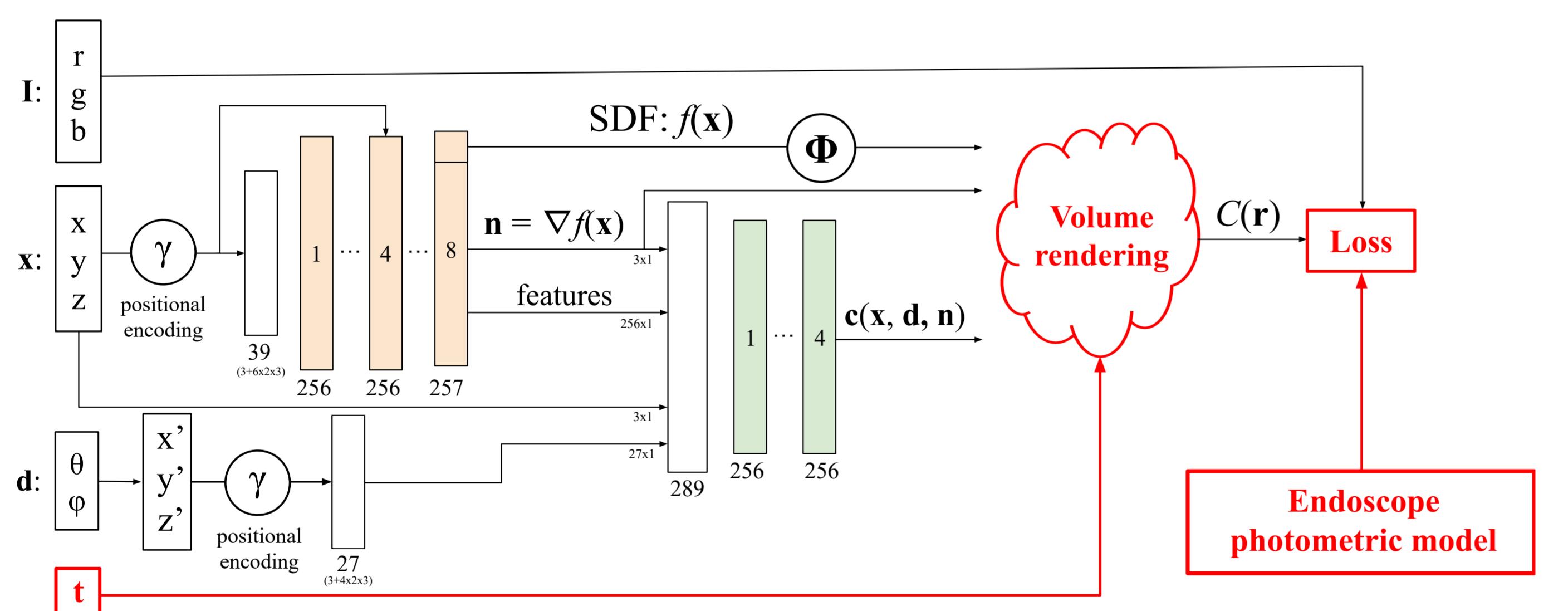


Fig 1. Benefits of illumination decline.

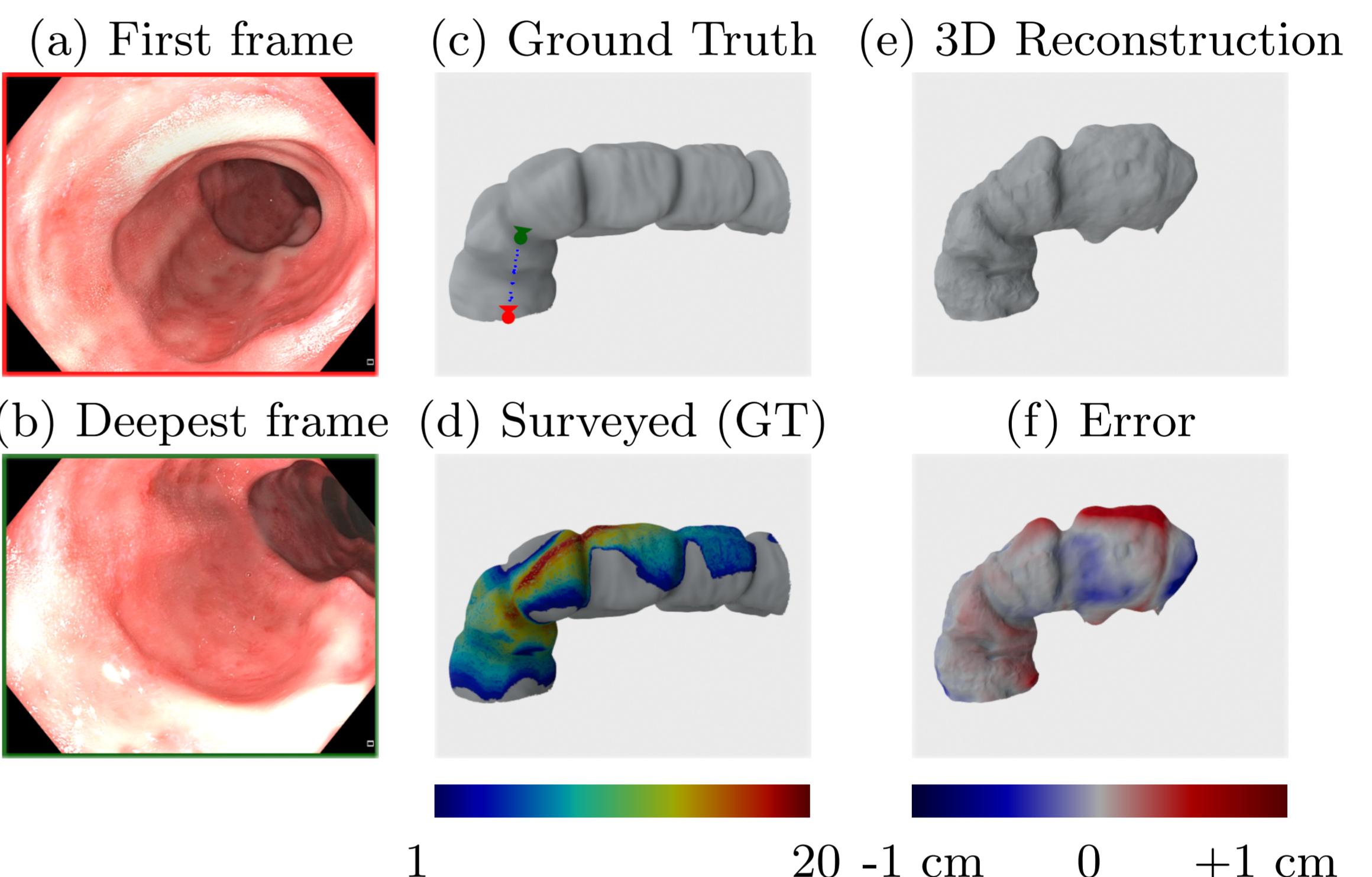


Fig 2. Reconstructing partially observed regions.

Takeaway

- ❖ Exploiting the illumination is key.
- ❖ Accuracies in the range of 3 mm.
- ❖ Reconstruction of unseen portions.

References

- [1] Wang, P. et al., "NeuS: Learning neural implicit surfaces by volume rendering for multi-view reconstruction". NeurIPS (2021)
- [2] Bobrow, T.L et al., "Colonoscopy 3D video dataset with paired depth from 2D-3D registration". (2022)

Quantitative results

Excellent accuracy on phantom imagery in the C3VD dataset [2]

- ❖ Different sections of the colon anatomy: Cecum, Descending, Sigmoid, Transverse.
- ❖ Reconstruction mean error of 2.80 mm.

Sequence	NeuS		LightNeuS (ours)																								
	C1a	C4b	C1a	C1b	C2a	C2b	C2c	C3a	C4a	C4b	D4a	S1a	S2a	S3a	S3b	T1a	T1b	T2a	T2b	T4a	Mean	T2c	T3a	T3b	T4b	Mean	
Sur.	MedAE	4.53	10.6	0.95	4.85	1.40	3.26	2.57	1.12	1.90	1.41	2.66	4.23	1.19	2.57	3.63	3.43	2.33	2.24	2.16	1.15	2.39	5.07	6.39	11.0	1.75	6.04
	MAE	5.07	10.6	1.48	5.11	1.54	3.65	3.00	2.54	2.14	1.63	3.26	4.33	1.89	2.68	4.16	3.47	2.72	2.28	2.30	2.31	2.80	5.45	8.65	12.1	6.70	8.23
	RMSE	6.40	11.6	2.01	5.63	1.87	4.39	3.74	5.49	2.92	2.10	4.08	4.96	2.78	3.18	4.81	4.07	3.34	2.58	2.70	3.79	3.58	6.48	10.7	14.4	11.3	10.7
Ext.	MedAE	4.68	5.35	0.83	4.89	1.41	3.32	2.54	1.27	1.91	1.45	4.50	4.01	1.40	2.87	3.54	3.38	2.69	2.19	2.12	1.29	2.53	4.44	6.54	13.6	8.00	8.16
	MAE	6.24	6.74	1.26	5.10	1.56	3.70	3.01	3.83	2.18	1.72	6.61	4.19	2.36	3.27	4.64	3.31	3.21	2.22	2.28	2.22	3.15	5.36	8.10	14.1	10.4	9.47
	RMSE	8.77	8.56	1.72	5.60	1.90	4.42	3.77	7.96	2.95	2.20	9.32	4.87	3.96	4.04	6.10	3.86	3.96	2.55	2.69	3.32	4.18	6.78	9.94	15.9	13.9	11.6