NEURAL INFORMATION PROCESSING SYSTEMS

Deep Non-line-of-sight Imaging from Under-scanning Measurements

Yue Li, Yueyi Zhang, Juntian Ye, Feihu Xu, Zhiwei Xiong

Poster: Thu 14 Dec 12:45 a.m. CST — 2:45 a.m. CST

Paper: https://openreview.net/pdf?id=JCN9YsZiwB

Project: https://github.com/Depth2World/Under-scanning_NLOS

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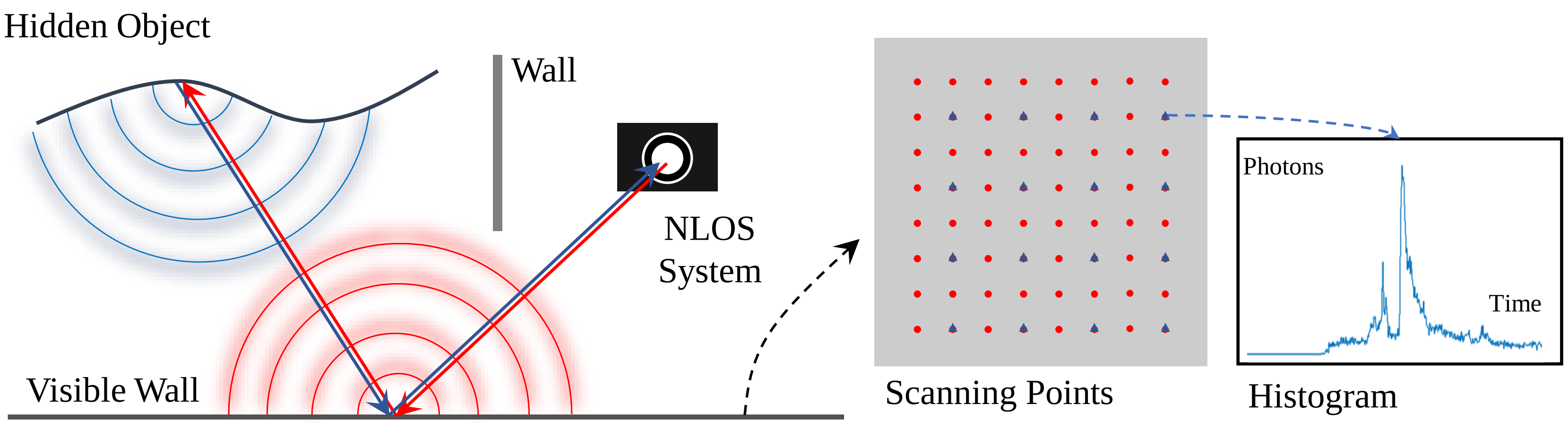
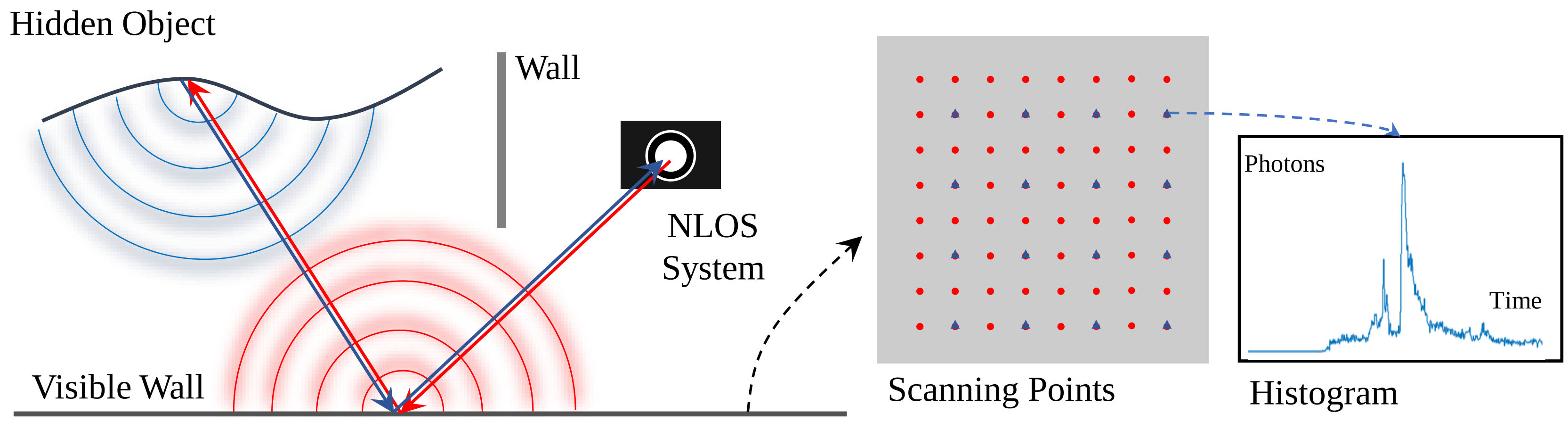
Non-Line-of-Sight Imaging (NLOS)

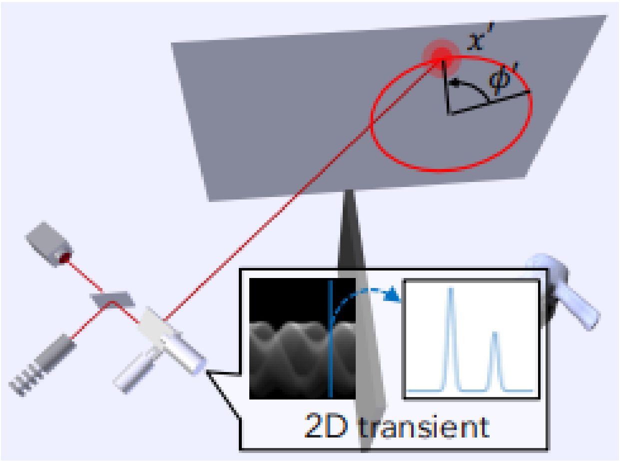


Non-Line-of-Sight Imaging

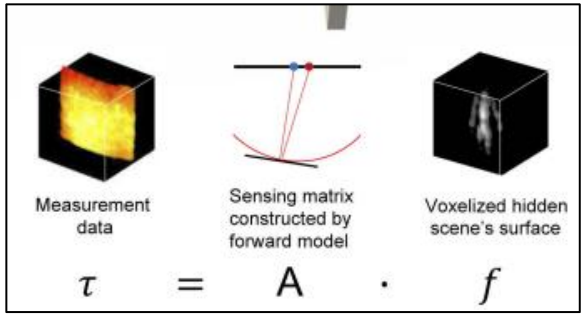


- Active confocal NLOS imaging has successfully enabled seeing around corners relying on high-quality transient measurements.
- The time-consuming dilemma raises the question of how to reconstruct the hidden volume from the under-scanning measurement (USM) without compromising the imaging quality.

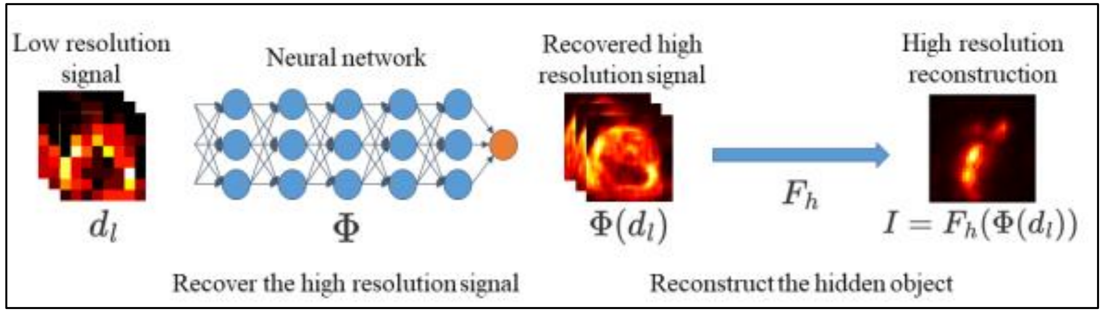
Related Work



C²NLOS



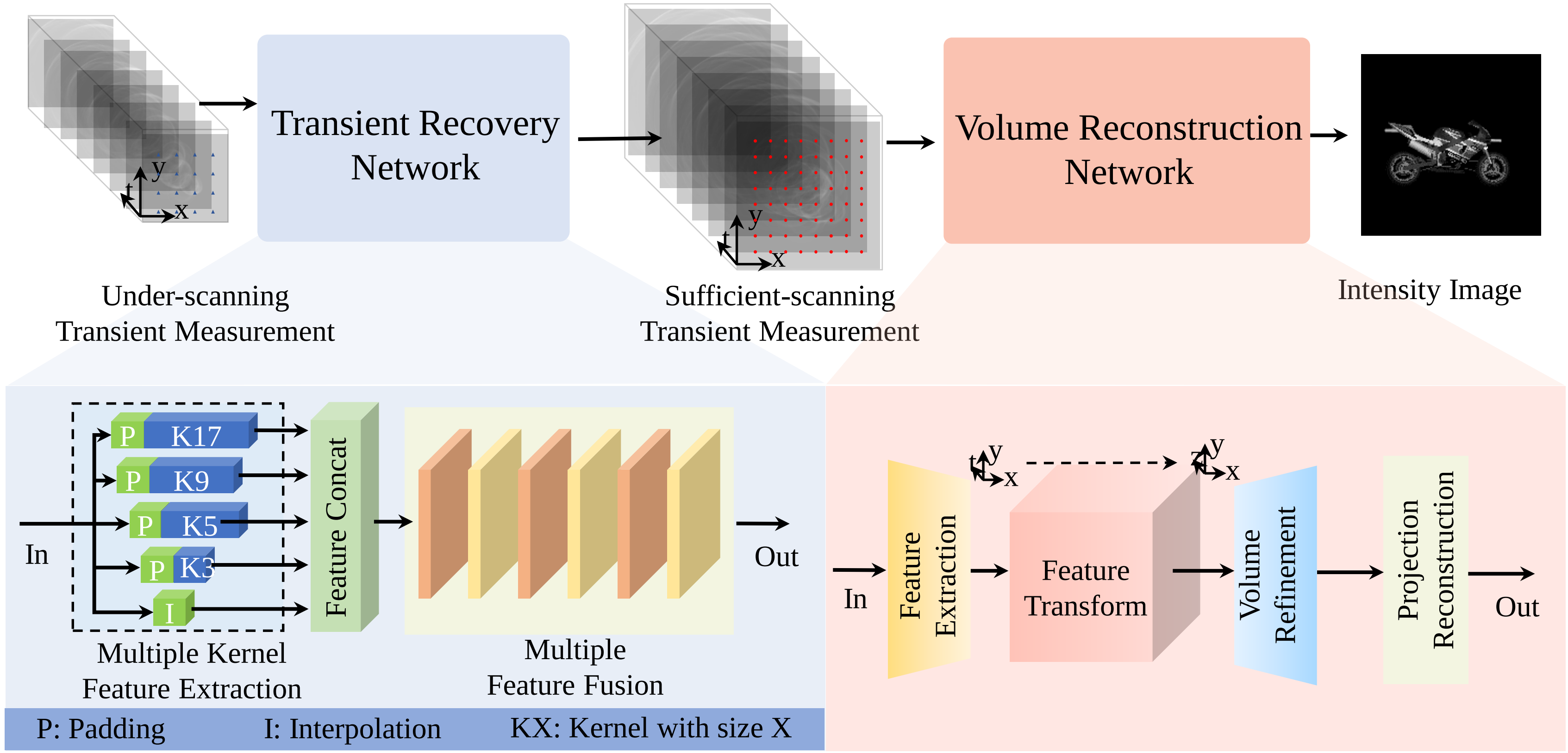
CSA



SSN

- We propose a new approach to NLOS reconstruction from the USM, pioneering the utilization of deep learning to achieve superior quality and swift inference.

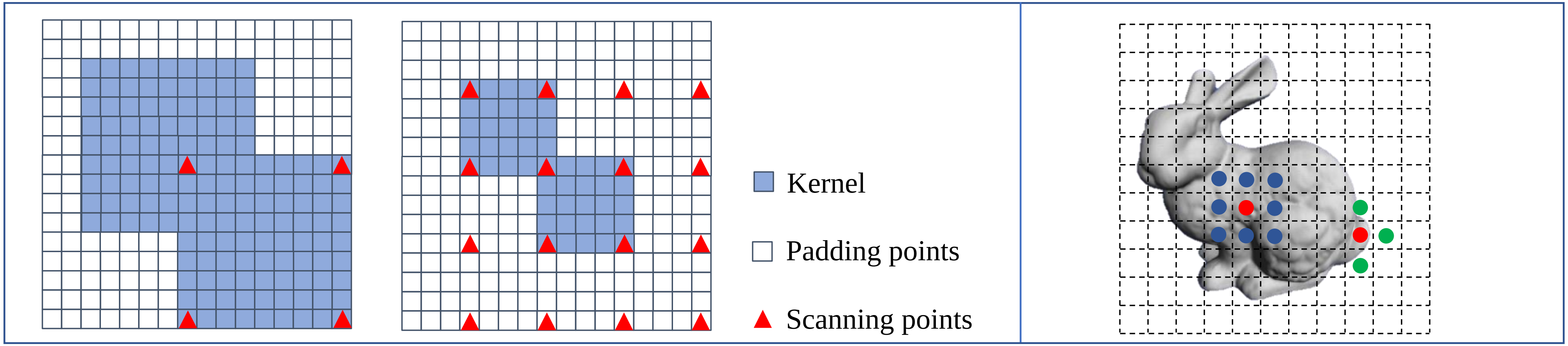
Proposed Method



Problem Formulation

$$\hat{\theta}_{\mathcal{T}}, \hat{\theta}_{\mathcal{V}} = \arg\min_{\theta_{\mathcal{T}}, \theta_{\mathcal{V}}} (\mathcal{L}(\boldsymbol{\tau}_u^{\uparrow}, \boldsymbol{\tau}_s) + \mathcal{L}(\boldsymbol{\rho}_u^{\uparrow}, \boldsymbol{\rho}_s) + \lambda\phi(\theta_{\mathcal{T}}, \theta_{\mathcal{V}}))$$

Proposed Method



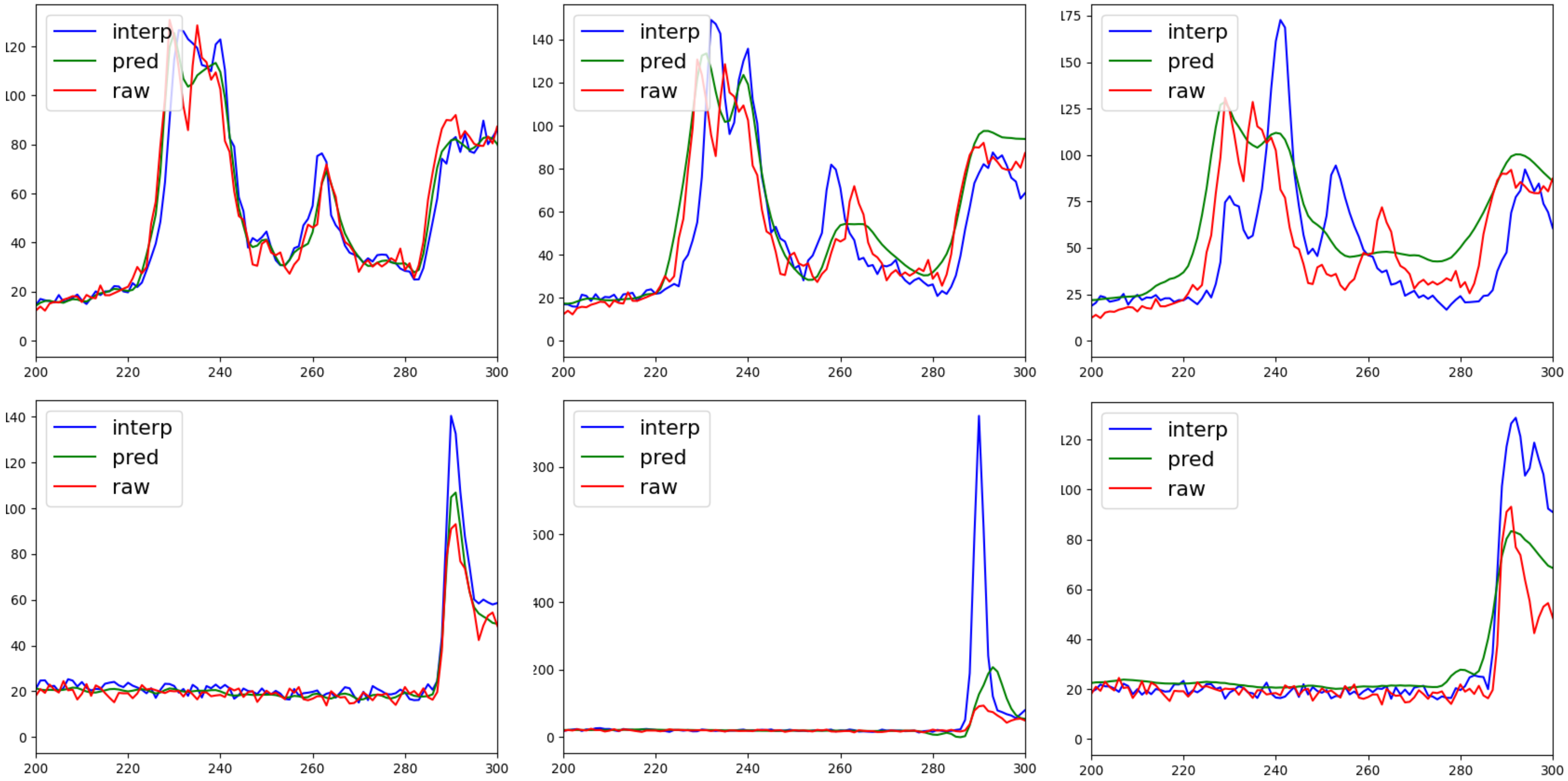
- The scanning points in the padded scanning grid are sparse and distant from each other.
- The large kernel perceives the distant regions, and the small kernel focuses on the local areas.

Regularized constraints

$$\mathcal{L}_{ls} = \sum_x \sum_u \sum_z ||\boldsymbol{\rho}(x,y,z) - \hat{\boldsymbol{\rho}}(x,y,z,k) \cdot W||_1,$$

$$\mathcal{L}_{tv} = \sum_x \sum_y \sum_z (||\boldsymbol{\rho}(x+1,y,z) - \boldsymbol{\rho}(x,y,z)||_1 + ||\boldsymbol{\rho}(x,y+1,z) - \boldsymbol{\rho}(x,y,z)||_1 + ||\boldsymbol{\rho}(x,y,z+1) - \boldsymbol{\rho}(x,y,z)||_1).$$

Results about Transient Recovery

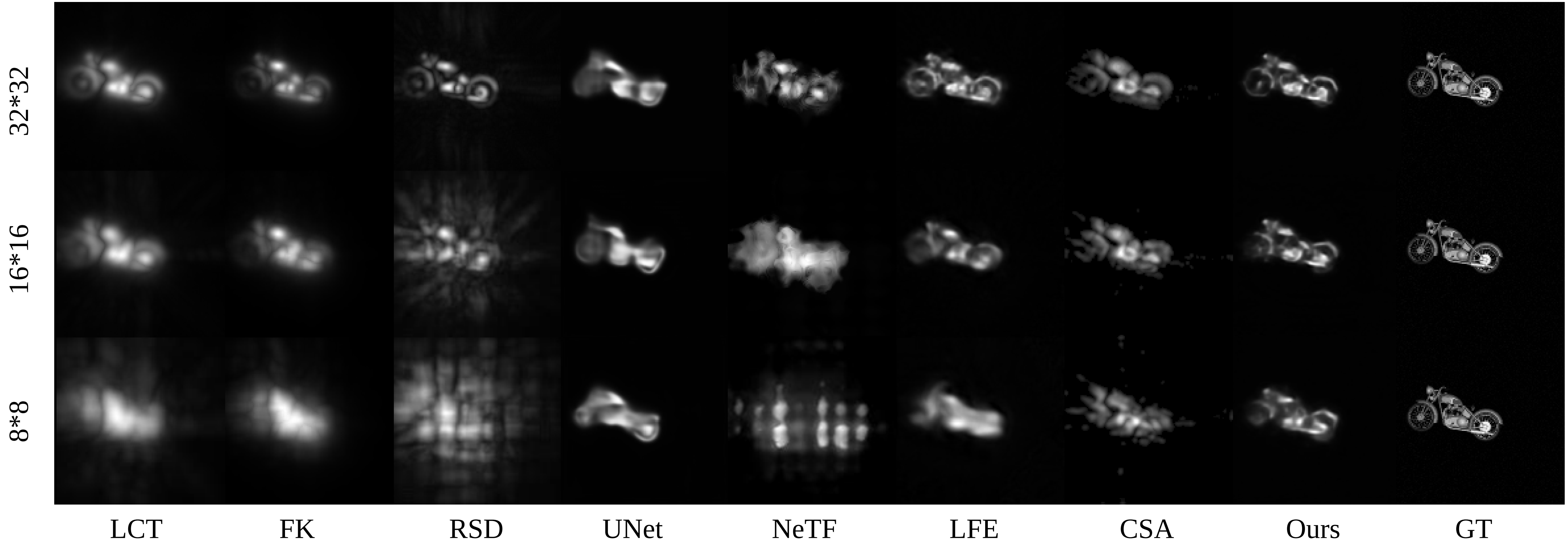


32×32 16×16 8×8

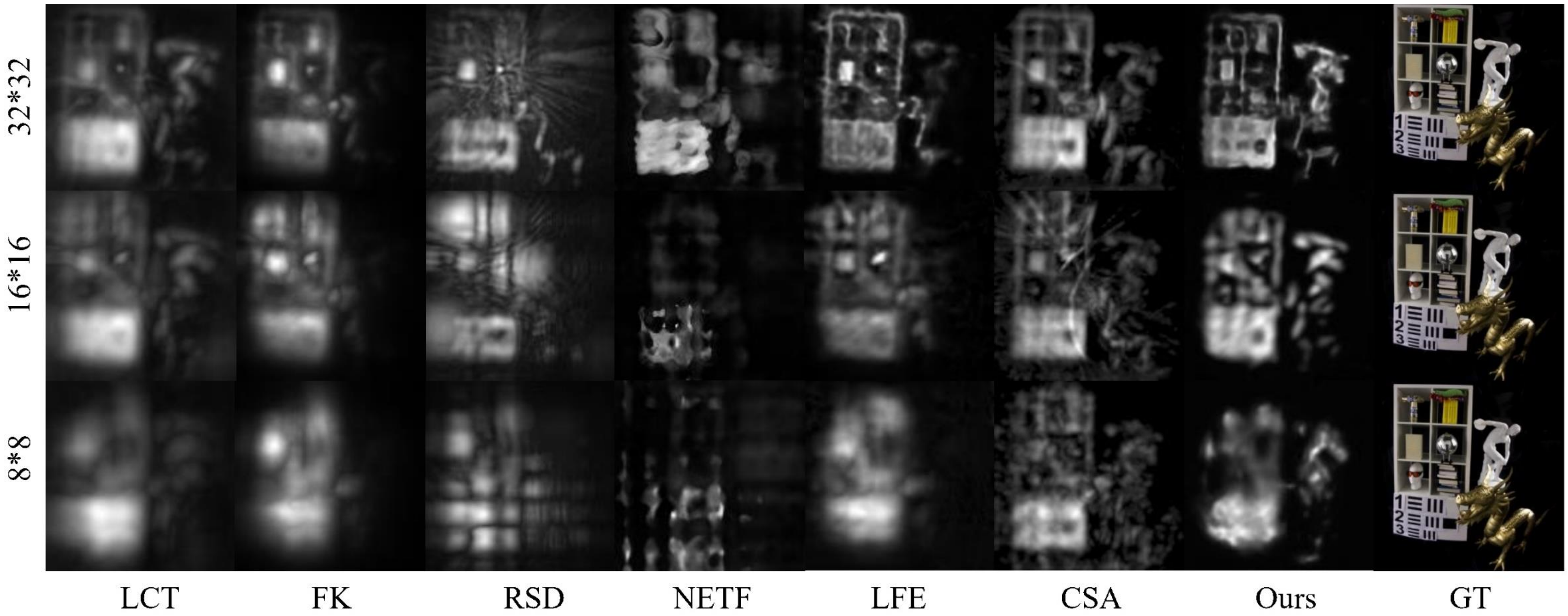
Results about Volume Reconstruction – Synthetic data

Points	Metrics	FBP [11]	LCT [12]	FK [14]	RSD [15]	UNet [28]	NeTF [35]	LFE [5]	CSA [17]	Ours
32×32	PSNR(dB)	21.12	22.07	24.59	25.44	26.71	22.85	27.94	23.22	**28.64**
	ACC(%)	0.52	56.54	15.48	69.09	73.71	68.25	73.05	30.43	**74.35**
	SSIM	0.2512	0.6314	0.4152	0.7847	0.8808	0.8691	0.8867	0.8223	**0.8975**
16×16	PSNR(dB)	15.69	20.27	18.02	23.53	26.64	19.14	27.04	22.62	**28.00**
	ACC(%)	0.05	20.16	5.99	60.86	73.79	62.38	72.40	25.83	**74.19**
	SSIM	0.0851	0.4335	0.2121	0.7102	0.8827	0.7977	0.8620	0.8064	**0.8929**
8×8	PSNR(dB)	12.31	15.85	17.20	19.77	26.28	17.03	26.10	21.46	**27.30**
	ACC(%)	0.031	2.64	7.21	32.54	73.56	54.87	72.17	15.56	**73.59**
	SSIM	0.0441	0.1981	0.2147	0.5131	0.8775	0.7639	0.8218	0.7976	**0.8789**

Results about Volume Reconstruction – Synthetic data

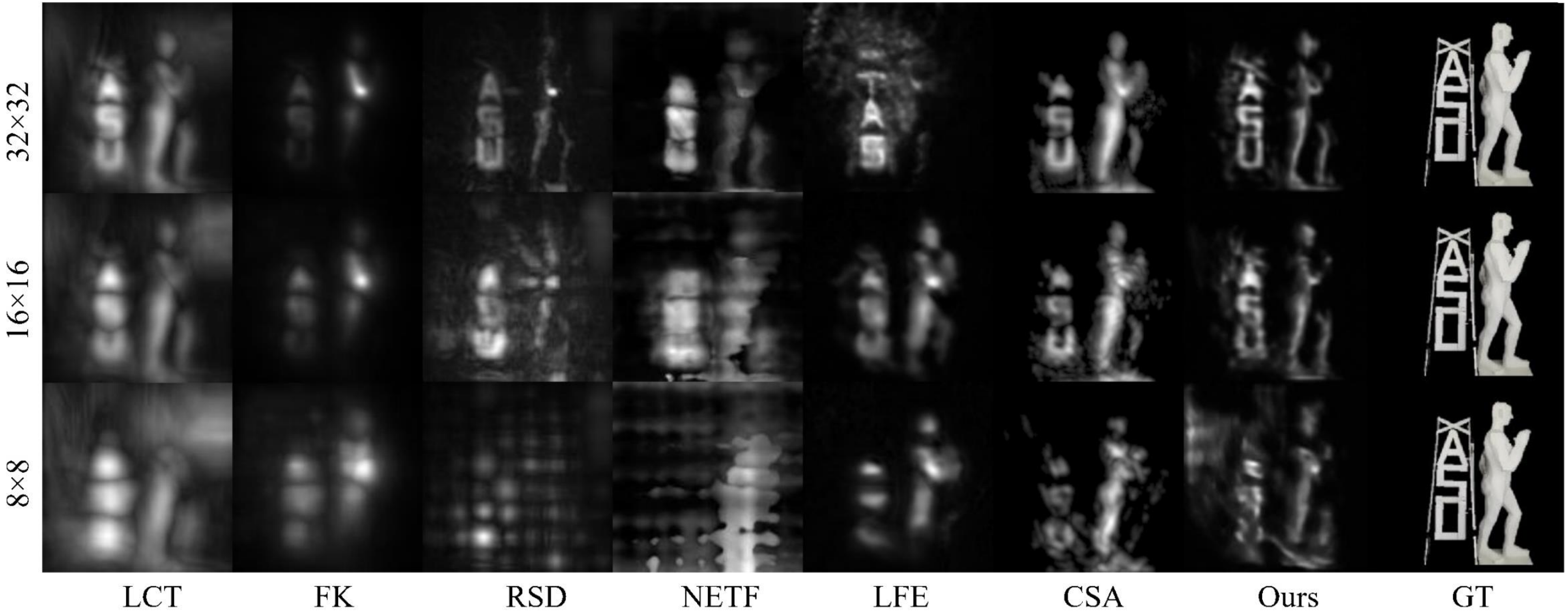


Results about Volume Reconstruction – Real-world data



Data captured by [Wave-based non-line-of-sight imaging using fast fk migration].

Results about Volume Reconstruction – Real-world data



Data captured by [NLOST: Non-line-of-sight imaging with transformer].

Inference Time

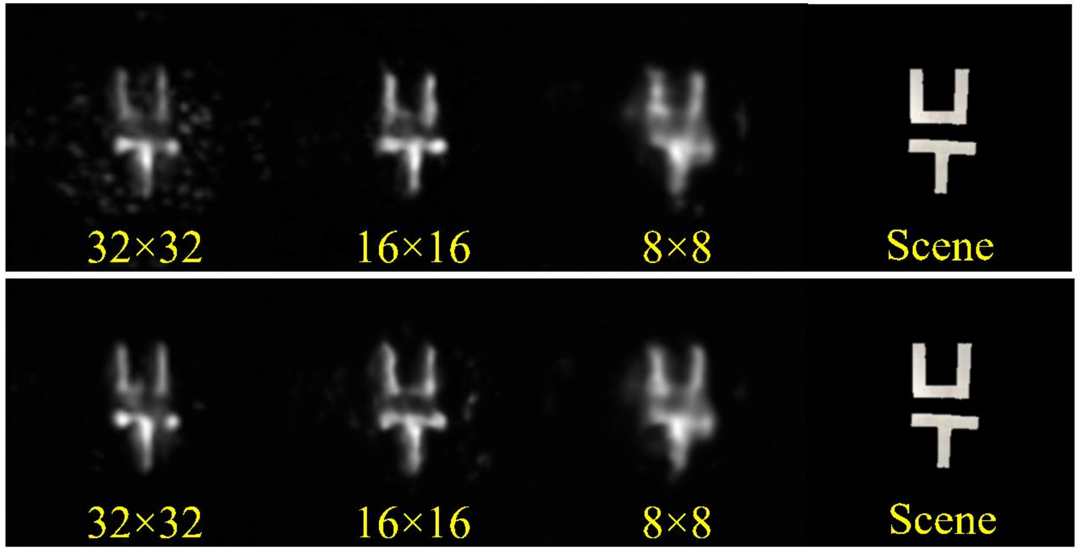
Method	FBP [11]	LCT [12]	FK [14]	RSD [15]	UNet [28]	NeTF [35]	LFE [5]	CSA [17]	Ours
Time (s)	0.042	0.034	0.061	0.038	0.162	2h-24h	0.030	20	0.420
Memory (M)	6026	6016	8056	10344	5642	2G-23G	4692	5306	7130

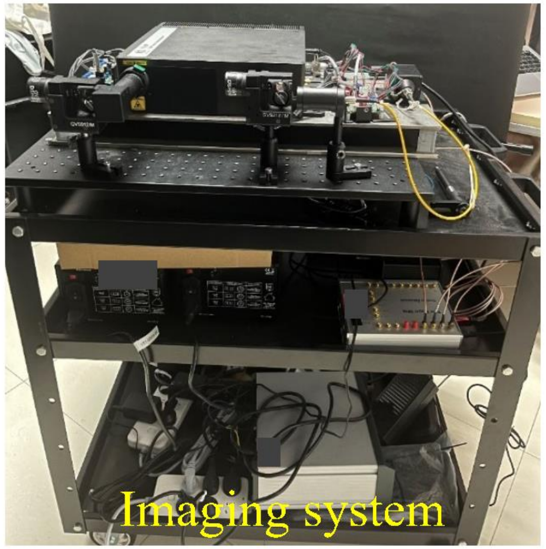
Result from Different Noise Levels

Total time

25.6s

102.4s





- Longer exposure times for fewer scanning points yield better imaging quality (Except for the extreme case 8×8).
- For our specific imaging system, employing a 16×16 scanning grid strikes a balance between the sampling points and the noise levels (**yet this would vary for different systems**).

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