

RoMo-GS: Efficient Online 3D Gaussian Splatting for Robot Mapping via Exposure-Integrated Motion Blur

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Project Page



arXiv



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Robotics and AI Institute

Motivation & Overview

Motion blur in robot mapping

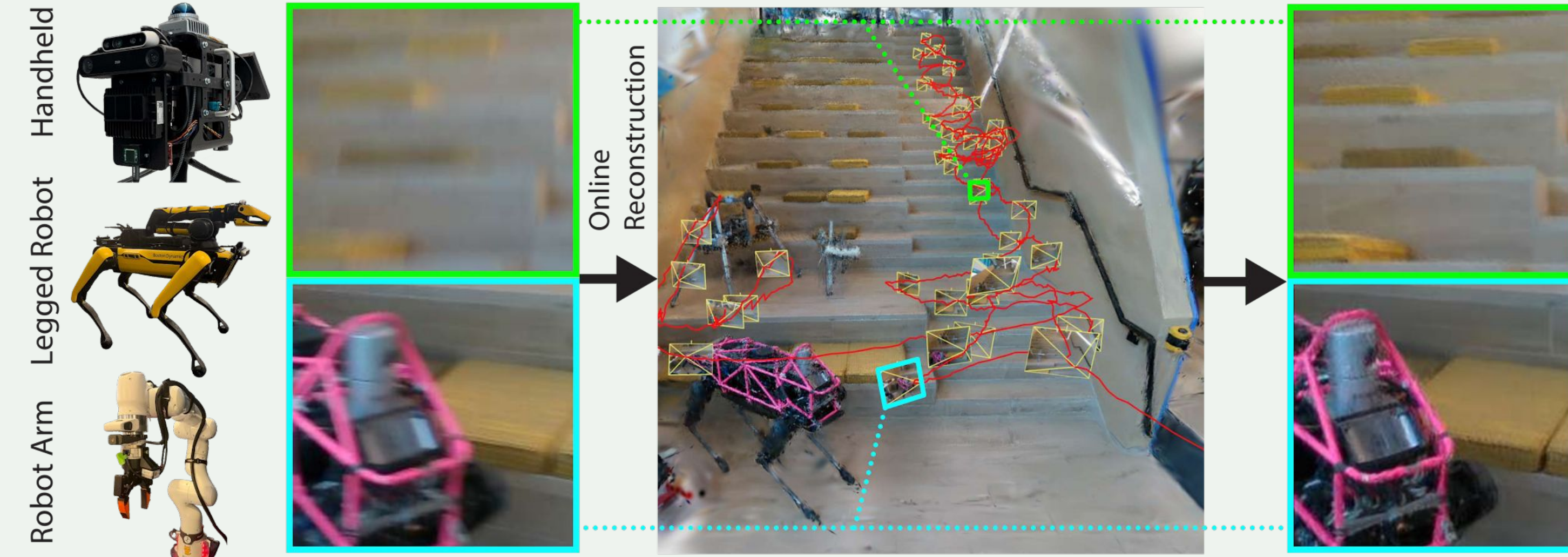
- Blurred observations degrade reconstruction during robot motion.

Computational cost of multi-sampling

- N rasterizations per observation, with $\mathbf{O}(N)$ computational cost.
- Larger N reduces artifacts but increases latency for online mapping.

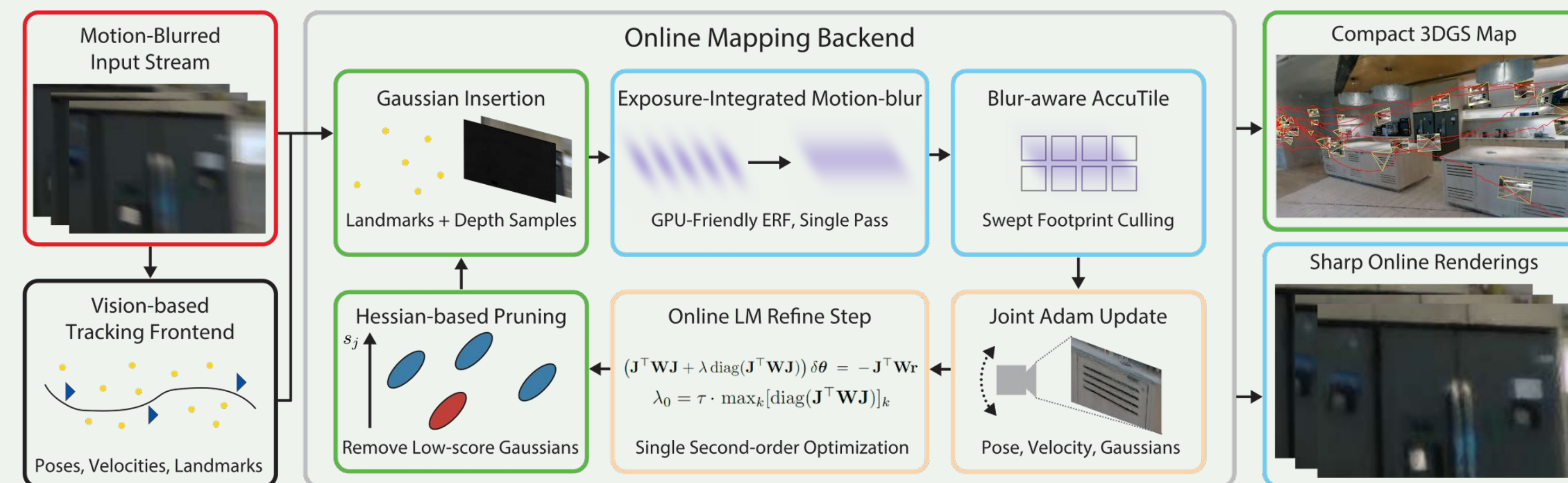
Online map growth

- Redundant Gaussians accumulate during continuous mapping.



(a) Input Blurry Images from Robots (b) Reconstructed Scene with Camera Trajectory (c) Rendered Sharp Images

Online Mapping Pipeline



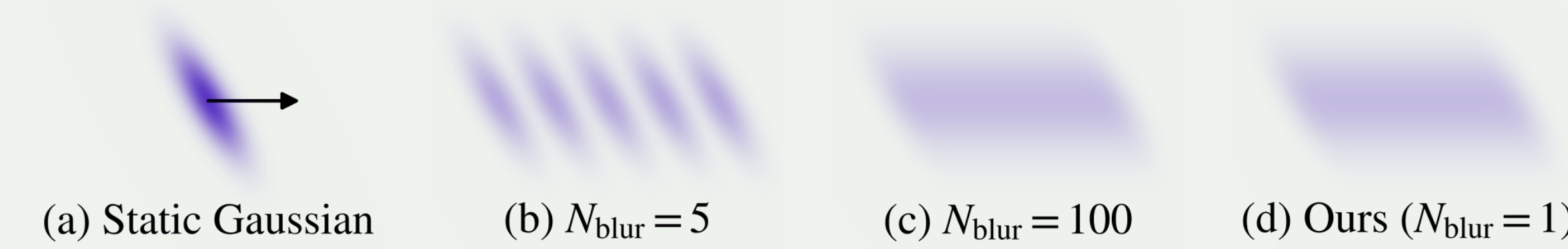
Exposure-Integrated Motion Blur

Screen-space motion

- Integrate projected opacity along a linear screen-space trajectory during the exposure.

$$\bar{\alpha}_j(x) = \frac{1}{t_e} \int_{-t_e/2}^{t_e/2} \alpha_j(x, \mu'_j + v'_j \tau) d\tau$$

$\tau \in [-t_e/2, t_e/2]$ t_e : exposure duration



Analytic evaluation

- Evaluate opacity with erf in one rasterization pass.
- $\mathbf{O}(1)$ cost per Gaussian, independent of sample count.

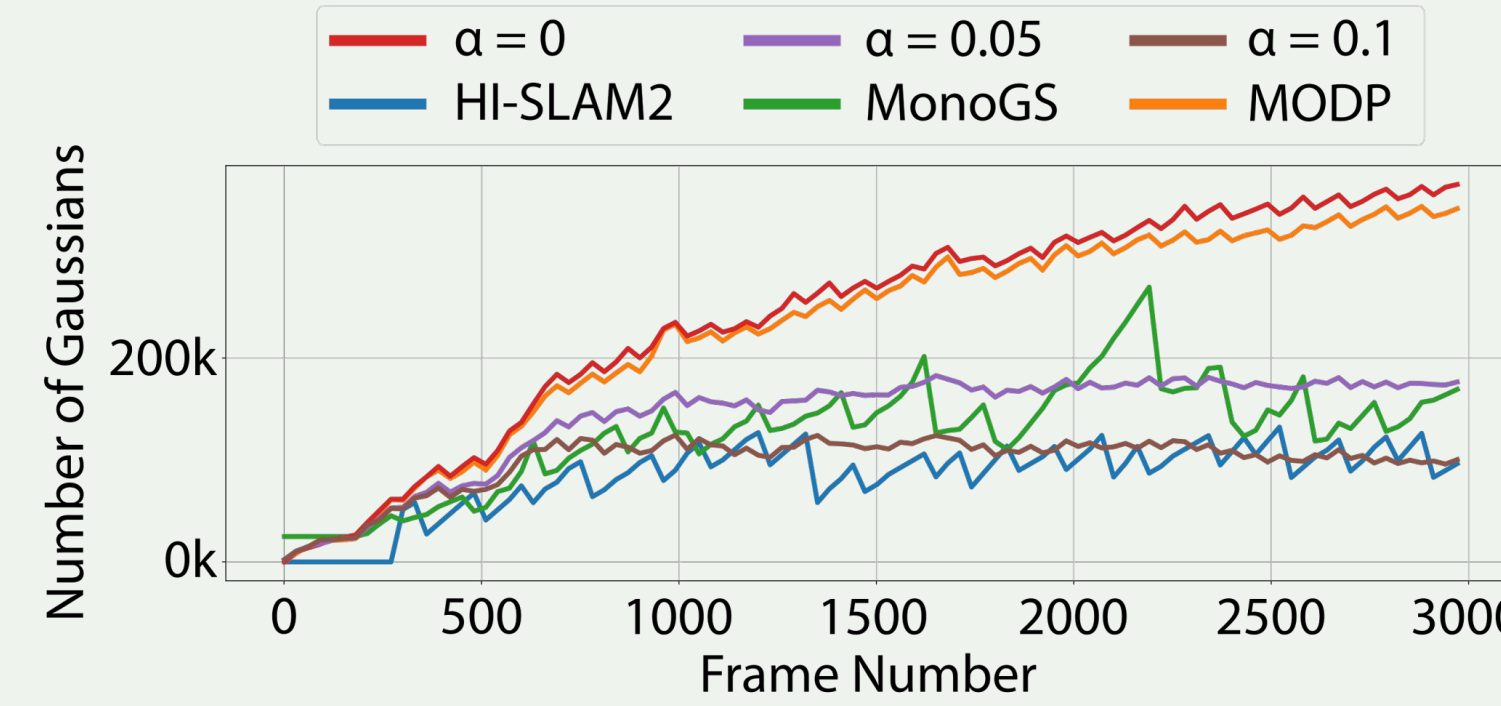
Hessian-Based Online Pruning

Opacity sensitivity

- Reuse opacity gradients from the online photometric loss.

$$s_j = \sum_i \sum_x \left(\frac{\partial L_i}{\partial o_j} \right)^2$$

- Prune low-score Gaussians observed in >10 keyframes.



dog_park: 3,000 frames, 4 loops

~20% fewer

Gaussians

compared with MODP

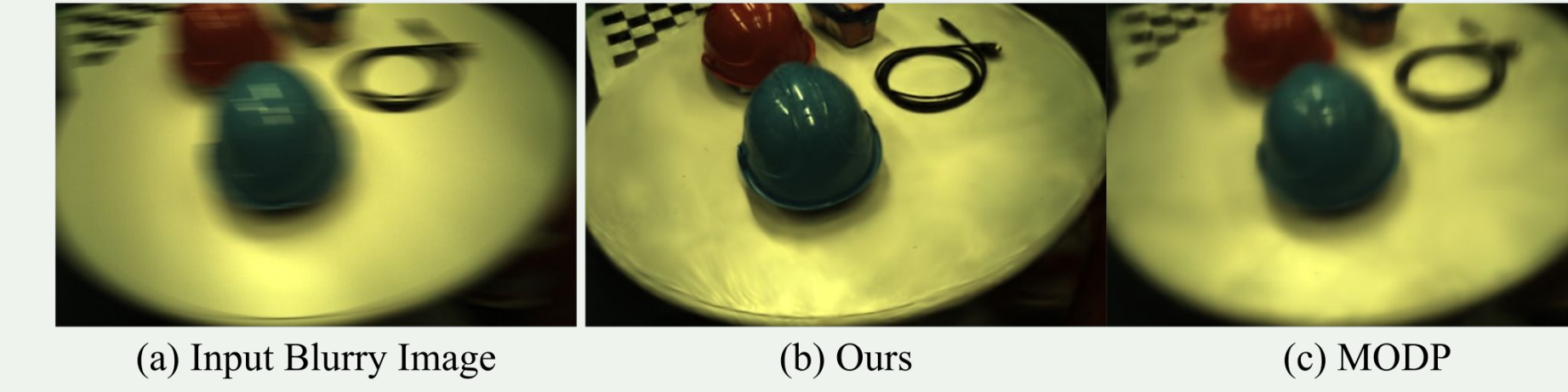
TUM: 167k vs. 210k

Custom: 309k vs. 386k

Comparable quality on TUM and custom datasets (blur model disabled).

Deblurring Quality & Efficiency

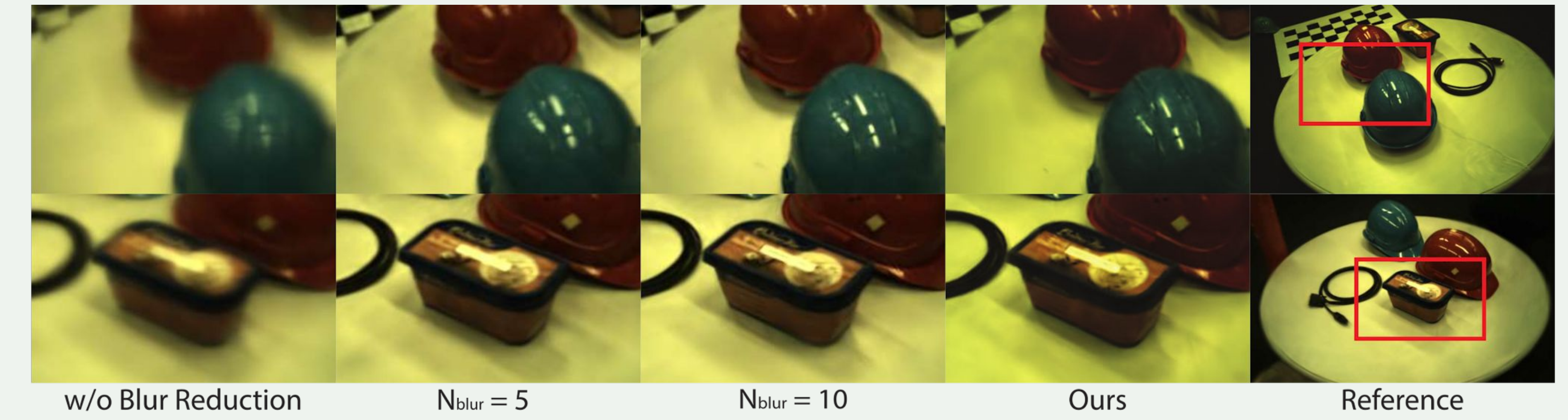
Online deblurring on ETH3D



ETH3D camera_shake_1 with BAD-Gaussians reference renderings.

Method	PSNR $\uparrow$	LPIPS $\downarrow$	# Gaussians
MODP	23.726	0.244	129,165
RoMo-GS	25.648	0.113	106,285

Exposure integration on ETH3D



Method	PSNR $\uparrow$	SSIM $\uparrow$	LPIPS $\downarrow$	FPS $\uparrow$	# Gaussians $\downarrow$
w/o blur reduction	24.355	0.892	0.202	5.698	129,128
Multi-sample, $N = 5$	25.951	0.911	0.121	2.448	124,831
Multi-sample, $N = 10$	26.003	0.911	0.107	1.592	126,902
RoMo-GS	25.367	0.905	0.113	3.695	117,669

2.32× faster than $N = 10$ multi-sampling

ETH3D comparison using the same mapping pipeline and BAD-Gaussians reference renderings.

Deblur-NeRF synthetic

~15–149× faster than offline baselines (total optimization time)

