THE UNIVERSITY of EDINBURGH

ENS DE LYON

Poster number: 2021

22-27 MAY 2022
ICASSP 2022
SINGAPORE

Sketched RT3D: How to Reconstruct Billions of Photons Per Second

Julián Tachella, Michael P. Sheehan and Mike Davies

Single-photon lidar

Pixelwise observation model

$$\pi(x_p|\boldsymbol{\alpha},\boldsymbol{t}) = \sum_{k=1}^{K} \alpha_k \pi_s(x_p|t_k) + \alpha_0 \pi_b(x_p)$$

DEPTHS

SURFACES PER PIXEL

BACKGROUND DISTRIBUTION

TIME-OF-ARRIVAL PTH PHOTON

REFECTIVITIES

SIGNAL DISTRIBUTION

Spatial regularization

- Most reconstruction methods define some $\rho(\boldsymbol{\theta})$ to promote smooth reconstructions [1]
- We choose RT3D which is real-time and multi-surface [2]

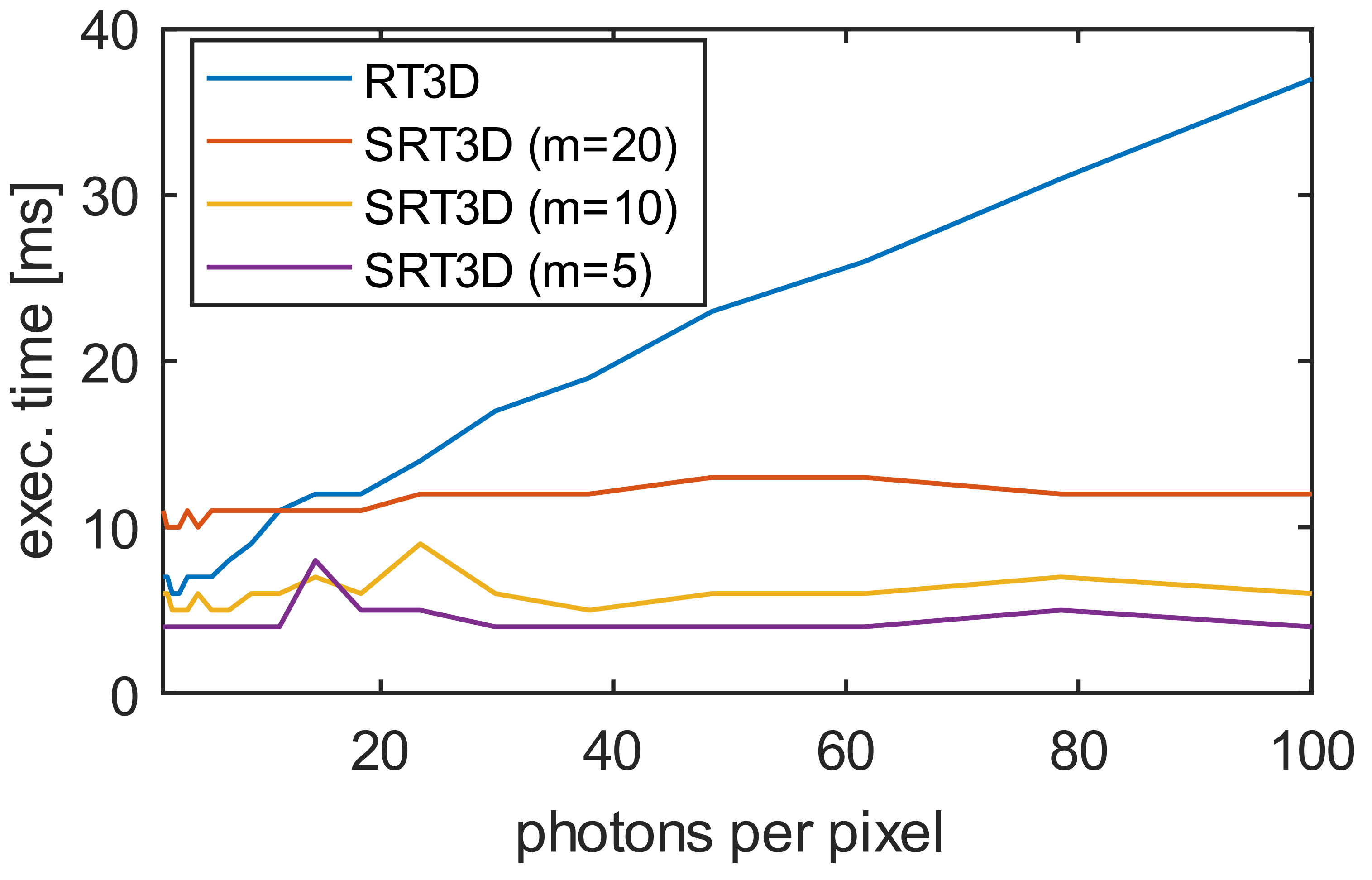
REFLECTIVITY + DEPTH PARAMETERS

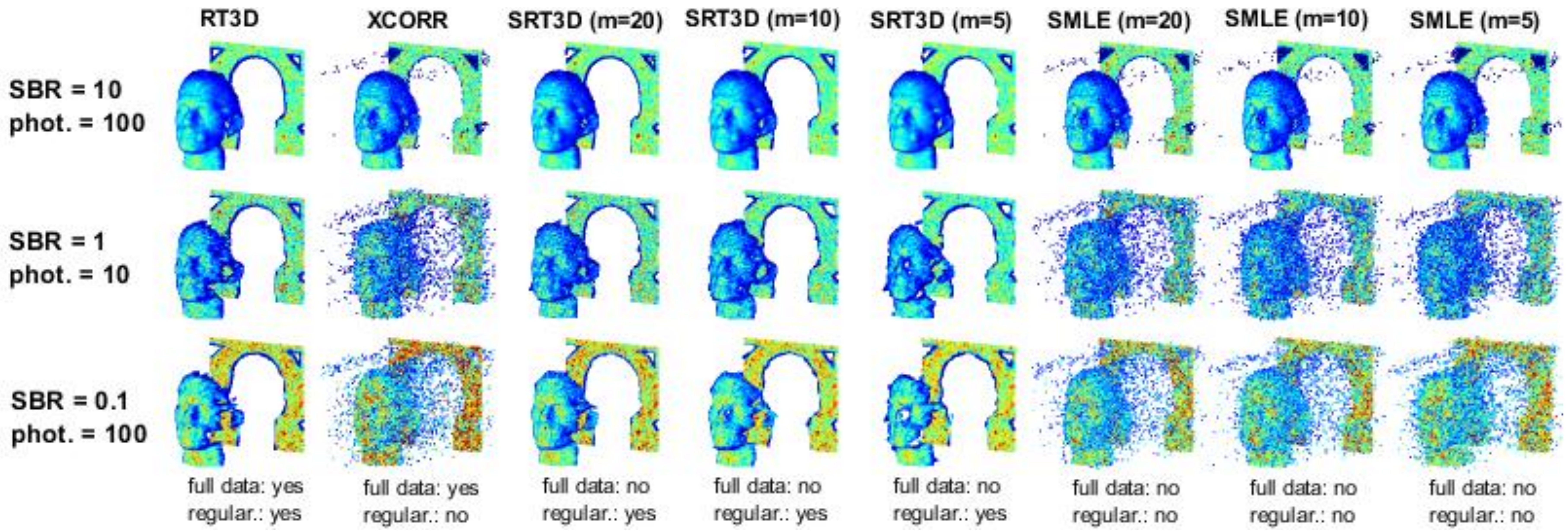
	Histogram-based $y \in \mathbb{R}^T$	**Sketched-based (ours)** $\boldsymbol{z} \in \mathbb{R}^{2m}$
Pixelwise Statistics	$y_\ell = \sum_{p=1}^{n} \mathbf{1}_{x_p \in [t_\ell, t_\ell+\Delta t]}$ *Poisson distrib.*	$z_\ell = \frac{1}{n}\sum_{p=1}^{n} e^{\mathrm{i}\omega_\ell x_p}$ $\approx$ *Gaussian distrib.*
Reconstruction Objective	$\arg\min_{\boldsymbol{\theta}} \sum_{i,j} f_{\boldsymbol{y}_{i,j}}(\theta_{i,j}) + \rho(\boldsymbol{\theta})$	$\arg\min_{\boldsymbol{\theta}} \sum_{i,j} \lVert \boldsymbol{z}_{i,j} - \mathbb{E}_{\boldsymbol{\theta}}\{\boldsymbol{z}_{i,j}\}\rVert^2 + \rho(\boldsymbol{\theta})$
Complexity	$\mathcal{O}(\min\{n,T\})$	$\mathcal{O}(sketches)$

Advantages of sketching

1. m (# sketches) ≈ K (# parameters) << T (# bins)
2. Computed **online** and **on-chip**
3. Less computation
4. Removes data transfer bottleneck

Experiments





[1] Rapp et al. "*Advances in Single-Photon Lidar for Autonomous Vehicles: Working Principles, Challenges, and Recent Advances*", IEEE SPM, 2020

[2] Tachella et al. "*Real-time 3D reconstruction from single-photon lidar data using plug-and-play point cloud denoisers*", Nature Communications, 2019

project website here