IMPERIAL

Neural LiDAR 3D Reconstruction

Reconstructing scenes from LiDAR data with Neural Radiance Field
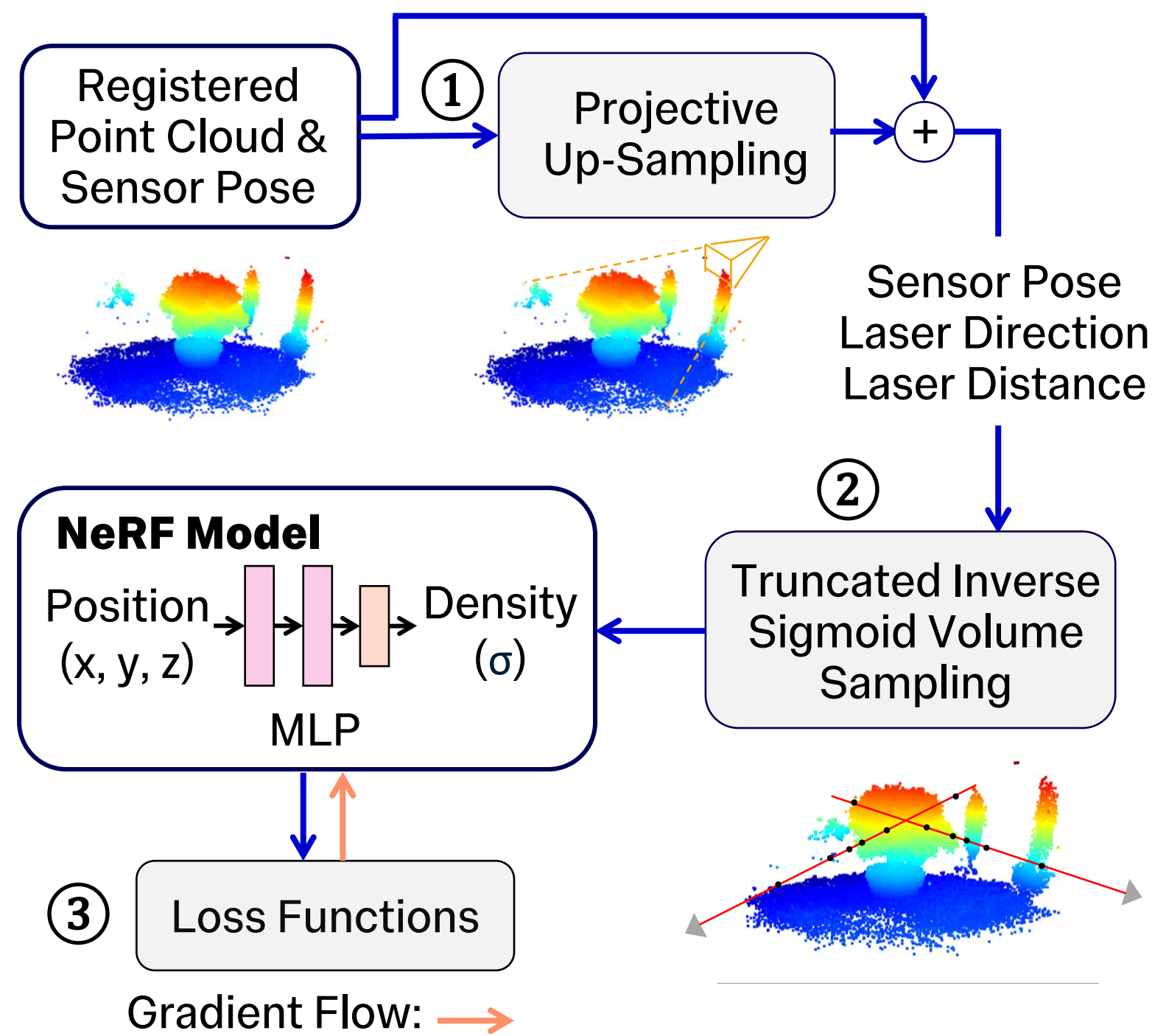
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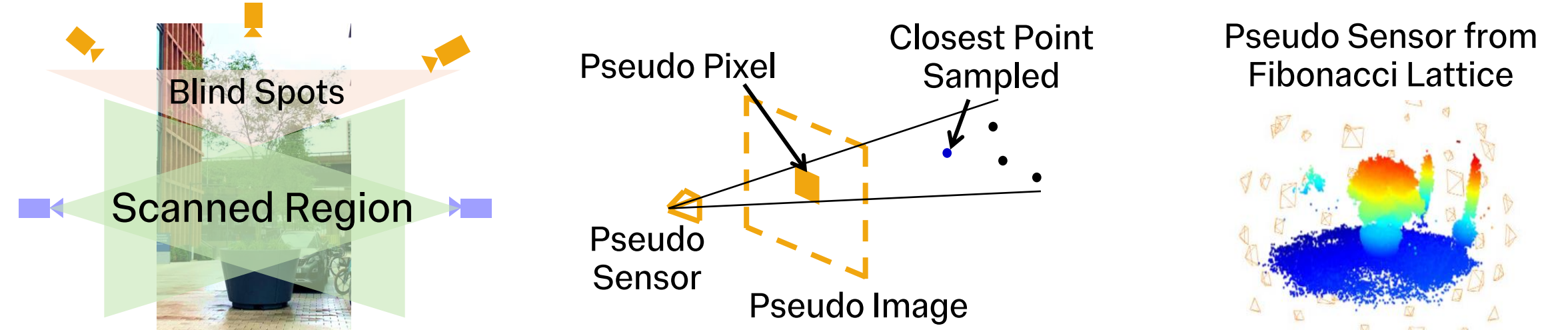## 1. Motivation

Dense LiDAR Mapping
- Consumes large amount of memory

Neural LiDAR 3D reconstruction
- Highly memory compact & resolution
- Robust for outdoor 3D reconstruction
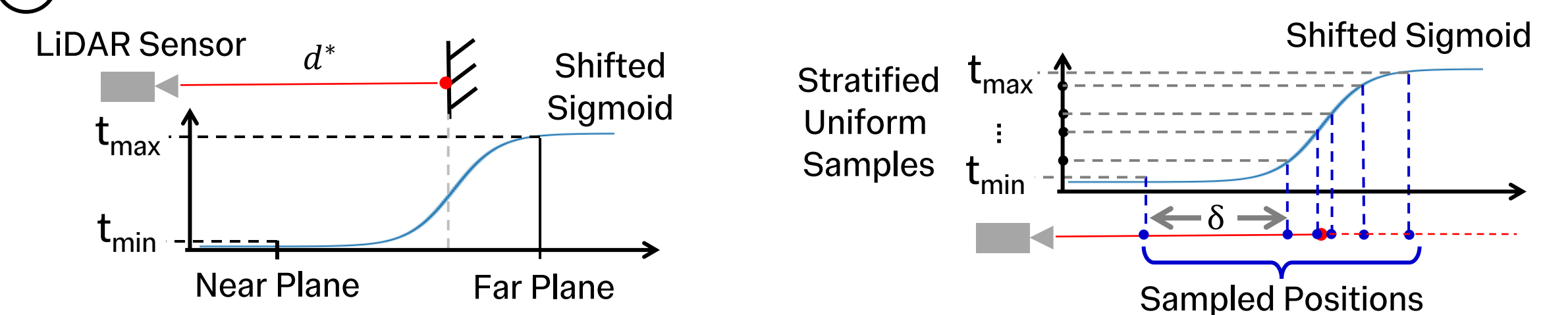- Applications in urban planning, mapping

Overview:

2. Method

① **Projective Up-Sampling** – Remove Noises in Blind Spots

② **Truncated Inverse Sigmoid Volume Sampling** – Sampling Around Surfaces

③ **Loss Functions** – Combined Loss

$*$ = Target   T = Cumulative Transmittnace
$\wedge$ = Estimate   h = Termination Distribution

Cumulative Transmittance Loss

$$T^* = 1 - \text{sigmoid}(d^* - x)$$

T^* :

$$\widehat{T}_i = \exp(-\Sigma_j^{i-1} \sigma_j \delta_j)$$

$$\mathcal{L}_T = \text{BCE\_Loss}(T^*, \widehat{T})$$

Termination Distribution Loss

$$h^* = \text{grad}(1 - T^*)$$

h^* :

$$\widehat{h}_i = \widehat{T}_i(1 - \exp(\sigma_i \delta_i))$$

$$\mathcal{L}_h = \text{KL\_Loss}(h^*, \widehat{h})$$

Distance Loss

$$d^* = \text{Measured}$$

$$\hat{d} = \Sigma_i(\widehat{h}_i \delta_i)$$

$$\mathcal{L}_d = \text{L1\_Loss}(d^*, \hat{d})$$

$$\mathcal{L}_{proposed} = \lambda_T \mathcal{L}_T + \lambda_h \mathcal{L}_h + \lambda_d \mathcal{L}_d$$
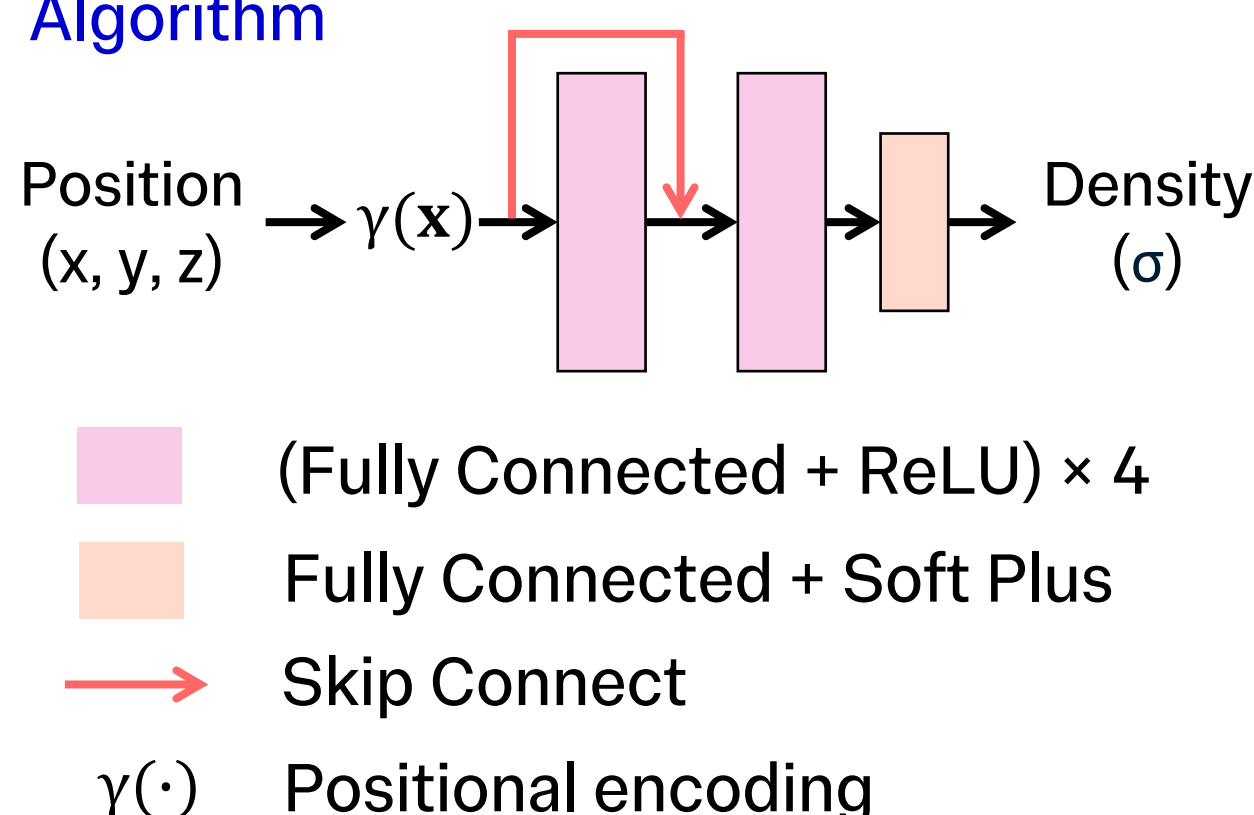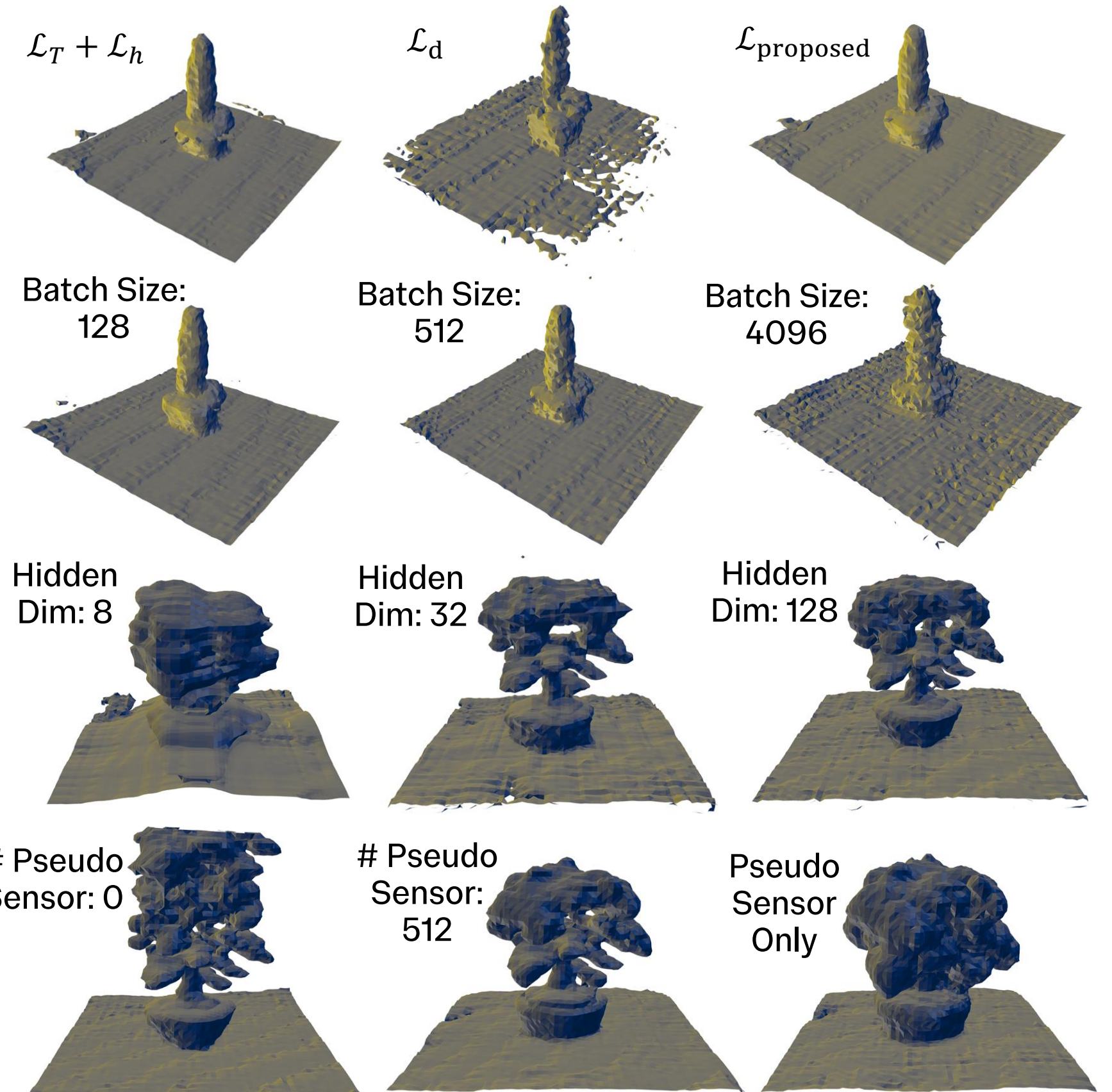
3. Experiment & Result

Data
- 3 datasets collected on objects around White City campus, with Livox Horizon LiDAR sensor [1], hand-held

Model Architecture
- Architecture inspired by NeRF in the wild [2]
- Soft Plus for output layer activation function to encourage non-negative value for density
- Model rendered with the Marching Cube Algorithm

- (Fully Connected + ReLU) × 4
- Fully Connected + Soft Plus
→ Skip Connect
$\gamma(\cdot)$ Positional encoding

Reconstruction Results

4. Discussion

- Dynamic object are omitted in reconstruction
- Model is robust to parameter reduction, reasonable construction result achieved with about 12500 parameters on single object
- Perspective up-sampling is effective in eliminating noise in blind spots
- Reconstruction quality is sensitive to point cloud registration quality
- Reconstruction result is smoother with smaller batch size

5. Conclusion

Major Contribution
- Proposed projective up sampling to mitigate noises
- Combined losses to achieve balanced reconstruction result

Future Work
- Conduct quantitative comparison
- More challenging settings & scenes or objects

Reference
[1] Livox, Livox horizon user manual, Accessed: 2024-08-09, 2024. [Online]. Available:
https://www.livoxtech.com/3296f540ecf5458a8829e01cf429798e/assets/horizon/Livox%20Horizon%20user%20manual%20v1.0.pdf.
[2] R. Martin-Brualla, et. al, Nerf in the wild: Neural radiance fields for unconstrained photo collections, 2021.arXiv: 2008.02268 [cs.CV]. [Online]. Available:
https://arxiv.org/abs/2008.02268.