DistillNeRF: Perceiving 3D Scenes from Single-Glance Images by Distilling Neural Fields and Foundation Model Features

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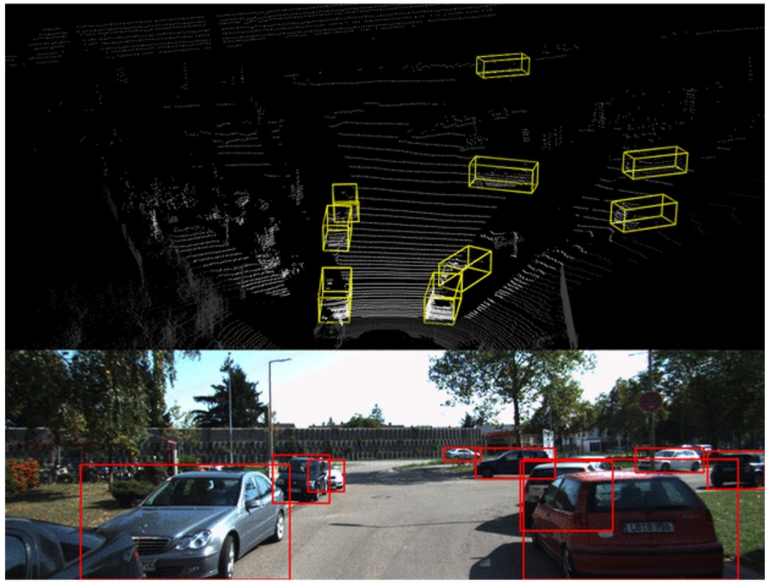
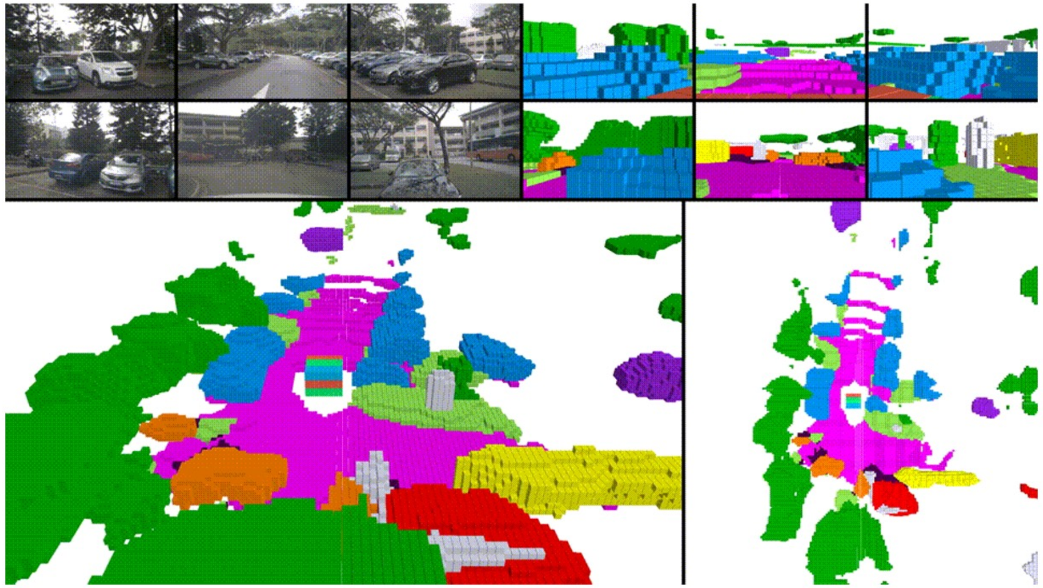
Perceiving the 3D World – Traditional Perception Tasks

- Various perception tasks have been proposed to perceive 3D world with 2D observations
  - Detection, tracking, segmentation, semantic occupancy…

- Hard to scale with a large of data
  - Industries have collected tons of data
  - But, the data annotation is painful: imagine you need to annotate each voxel for the scene…

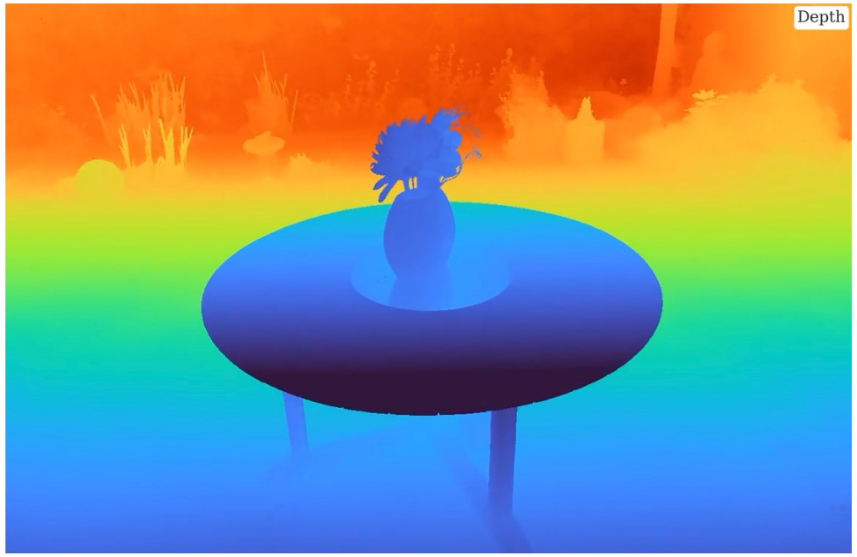


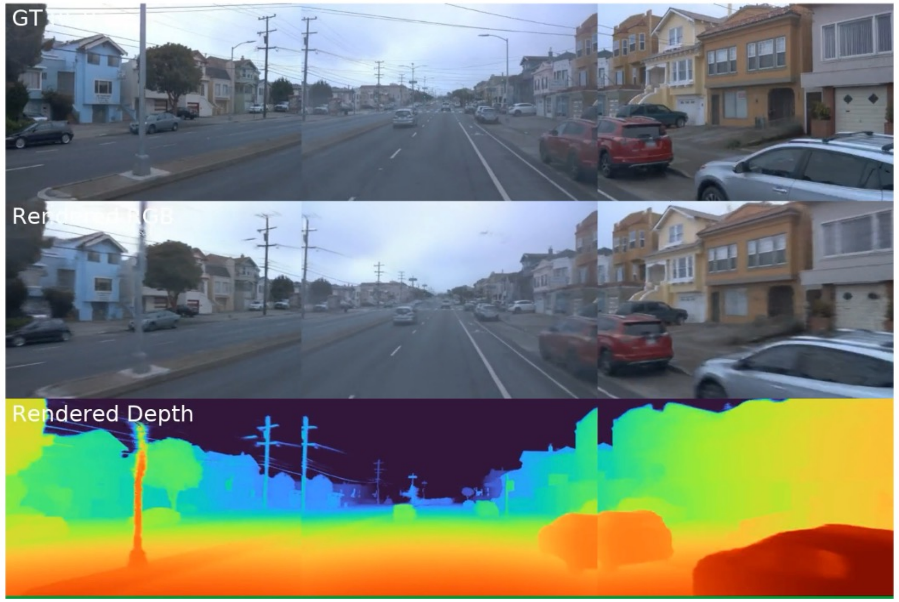


- Liang, M., Yang, B., Chen, Y., Hu, R. and Urtasun, R., 2019. Multi-task multi-sensor fusion for 3d object detection. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition* (pp. 7345-7353).
- Huang, Y., Zheng, W., Zhang, Y., Zhou, J. and Lu, J., 2023. Tri-perspective view for vision-based 3d semantic occupancy prediction. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition* (pp. 9223-9232).

Neural Radiance Fields (NeRF)

- Self-supervised learning: reconstruct the scene with RGB and optional LiDAR as inputs and supervision
- Very popular and fast-moving topic
- From simple objects, to unbounded scene, to autonomous driving scenes recently

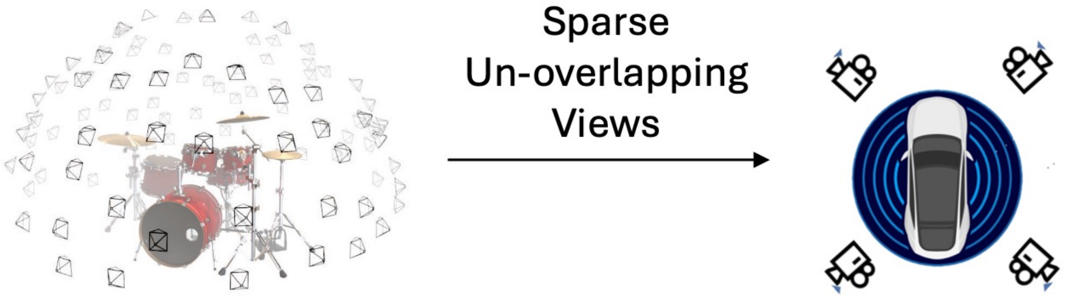




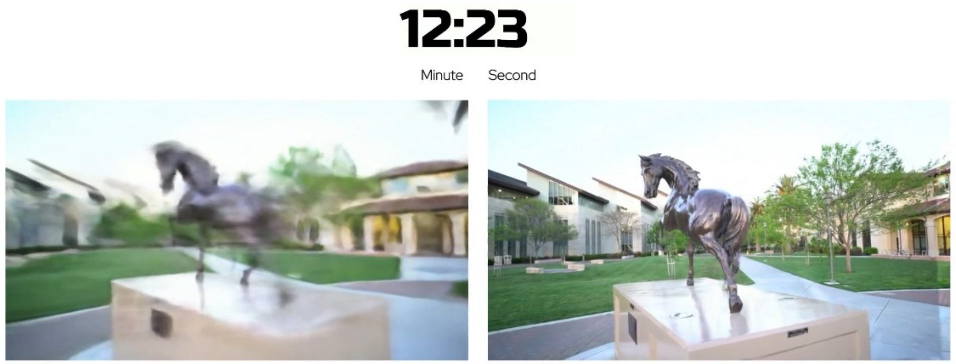
- Barron, J.T., Mildenhall, B., Verbin, D., Srinivasan, P.P. and Hedman, P., 2022. Mip-nerf 360: Unbounded anti-aliased neural radiance fields. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 5470-5479).
- Yang, J., Ivanovic, B., Litany, O., Weng, X., Kim, S.W., Li, B., Che, T., Xu, D., Fidler, S., Pavone, M. and Wang, Y., 2023. Emernerf: Emergent spatial-temporal scene decomposition via self-supervision. arXiv preprint arXiv:2311.02077.

Neural Radiance Fields (NeRF)

- Sounds all good! What could be wrong?
  - Requires a large number of overlapping images
  - Need training for each scene at test time, which take hours/minutes/seconds
  - Only focus on view-synthesis tasks, lack rich semantics in learned 3D representations
- Issues for autonomous driving
  - Sparse cameras with limited overlaps on vehicle, usually 4/6 cameras
  - Need to run in real time for online driving - usually only ~0.1s latency is allowed for on-vehicle computation
  - Need models with capabilities in downstream tasks



Sparse Un-overlapping Views



NoPe-NeRF

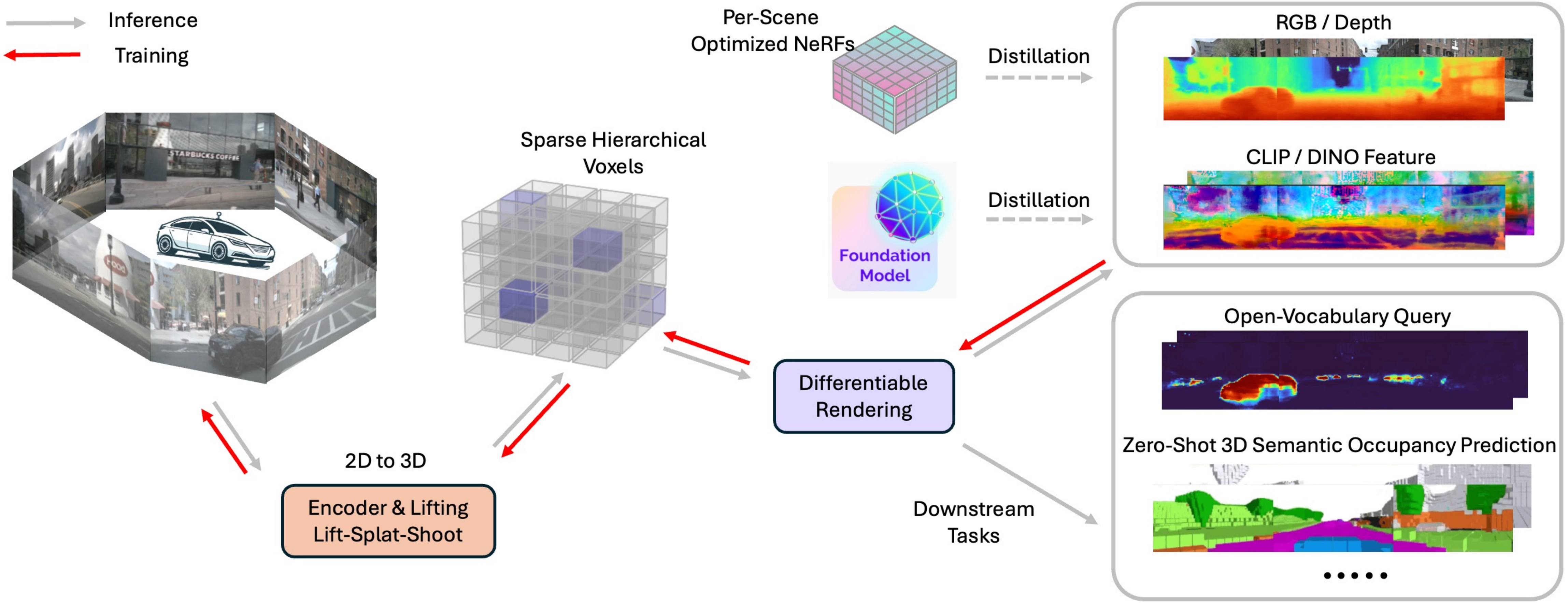
Ours (9s ✔)

Can we bring NeRF to handle sparse non-overlapping views, be online and generalizable to new scenes, and support downstream tasks?

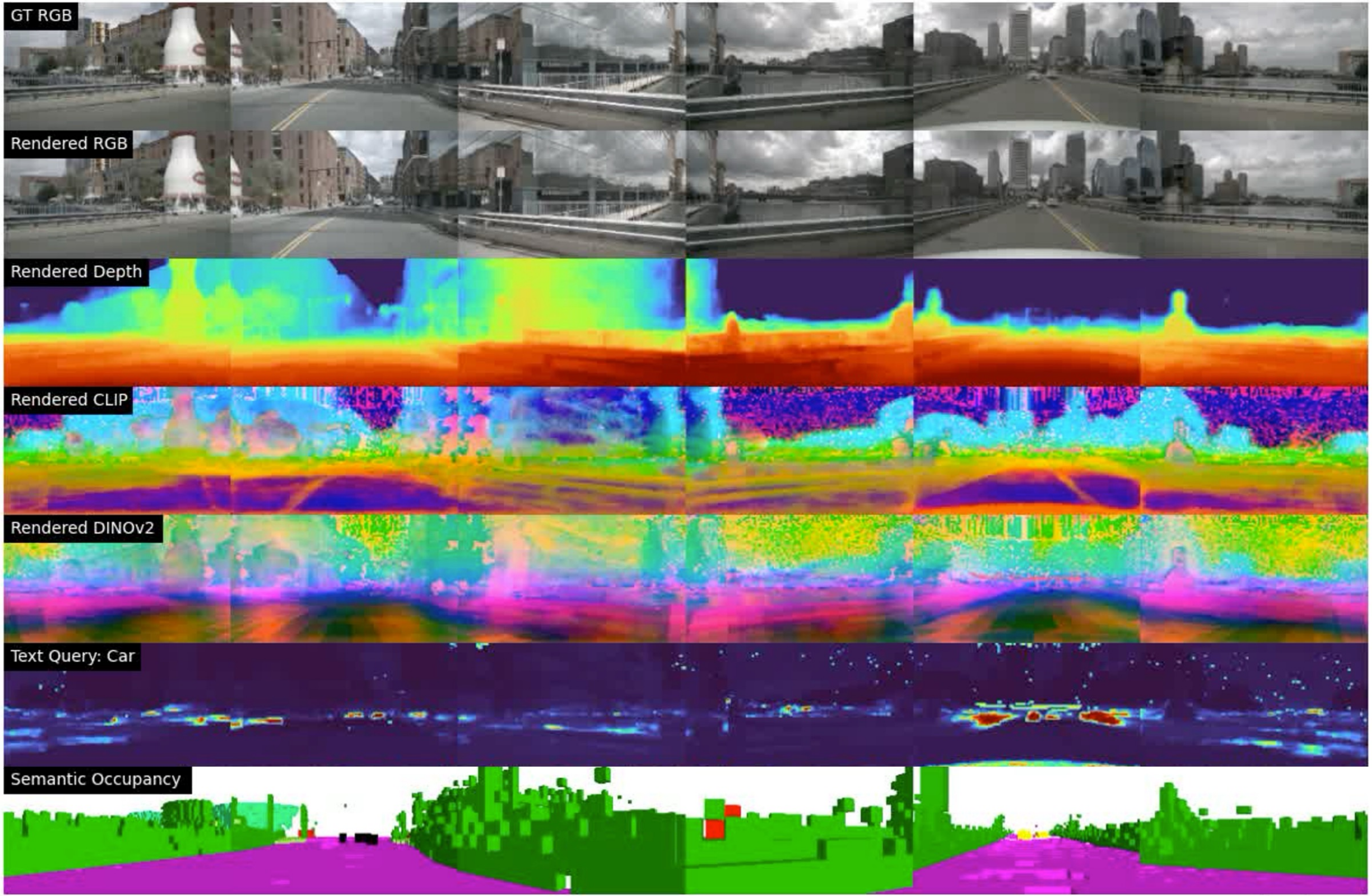
- Fan, Z., Cong, W., Wen, K., Wang, K., Zhang, J., Ding, X., Xu, D., Ivanovic, B., Pavone, M., Pavlakos, G. and Wang, Z., 2024. Instantsplat: Unbounded sparse-view pose-free gaussian splatting in 40 seconds. *arXiv preprint arXiv:2403.20309*.

Our Approach - DistillNeRF

- An online model that lifts 2D features into 3D, and can render RGB/depths, without test-time per-scene training
- Distill a bunch of per-scene optimized NeRFs into one online model, for enhanced 3D geometry
- Distill foundation model features into the online model, for enriched semantics
- Support downstream tasks: rendering, open-vocabulary query, zero-shot semantic occupancy prediction



Capabilities: Rendering without Test-Time Per-Scene Optimization, Enable Zero-Shot Downstream Tasks



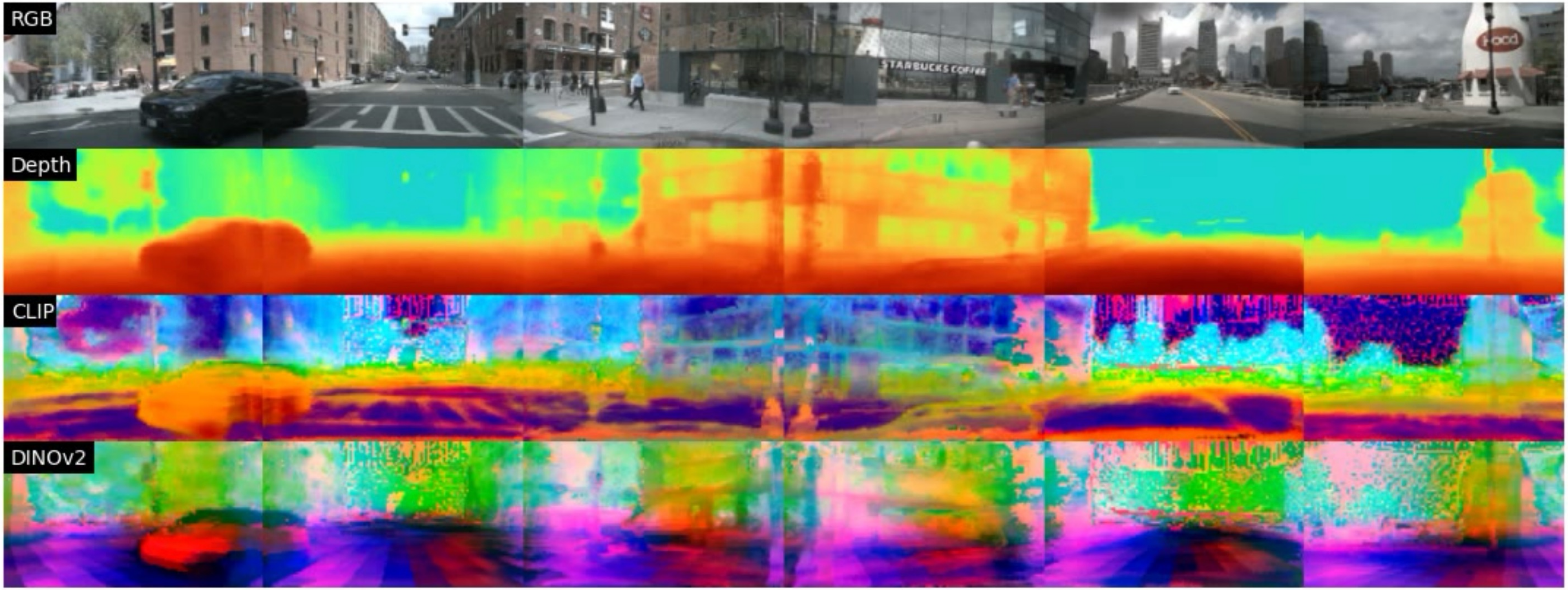
Single-Frame Input

Scene Reconstruction

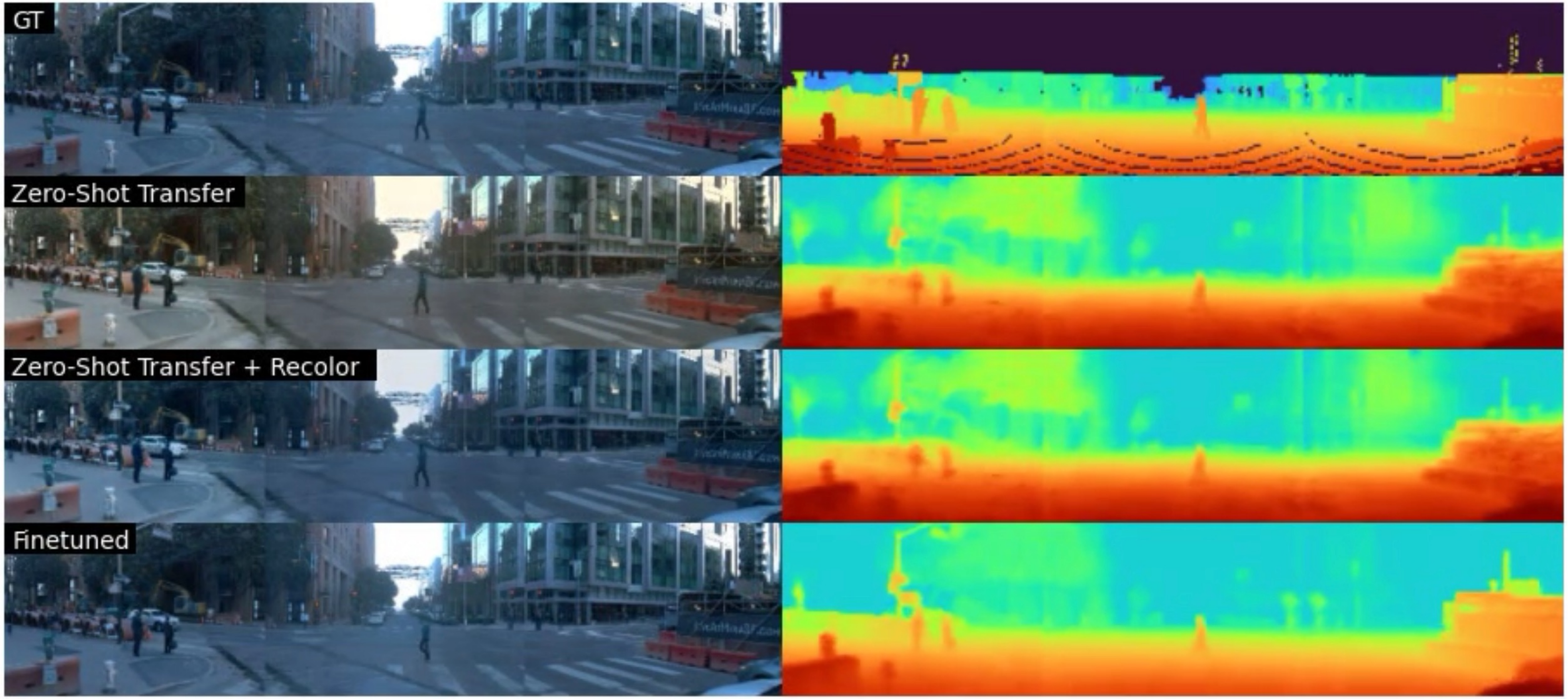
Foundation Model Feature Prediction

Downstream Tasks

Novel View Synthesis without test-time per-scene optimization, given single-frame images

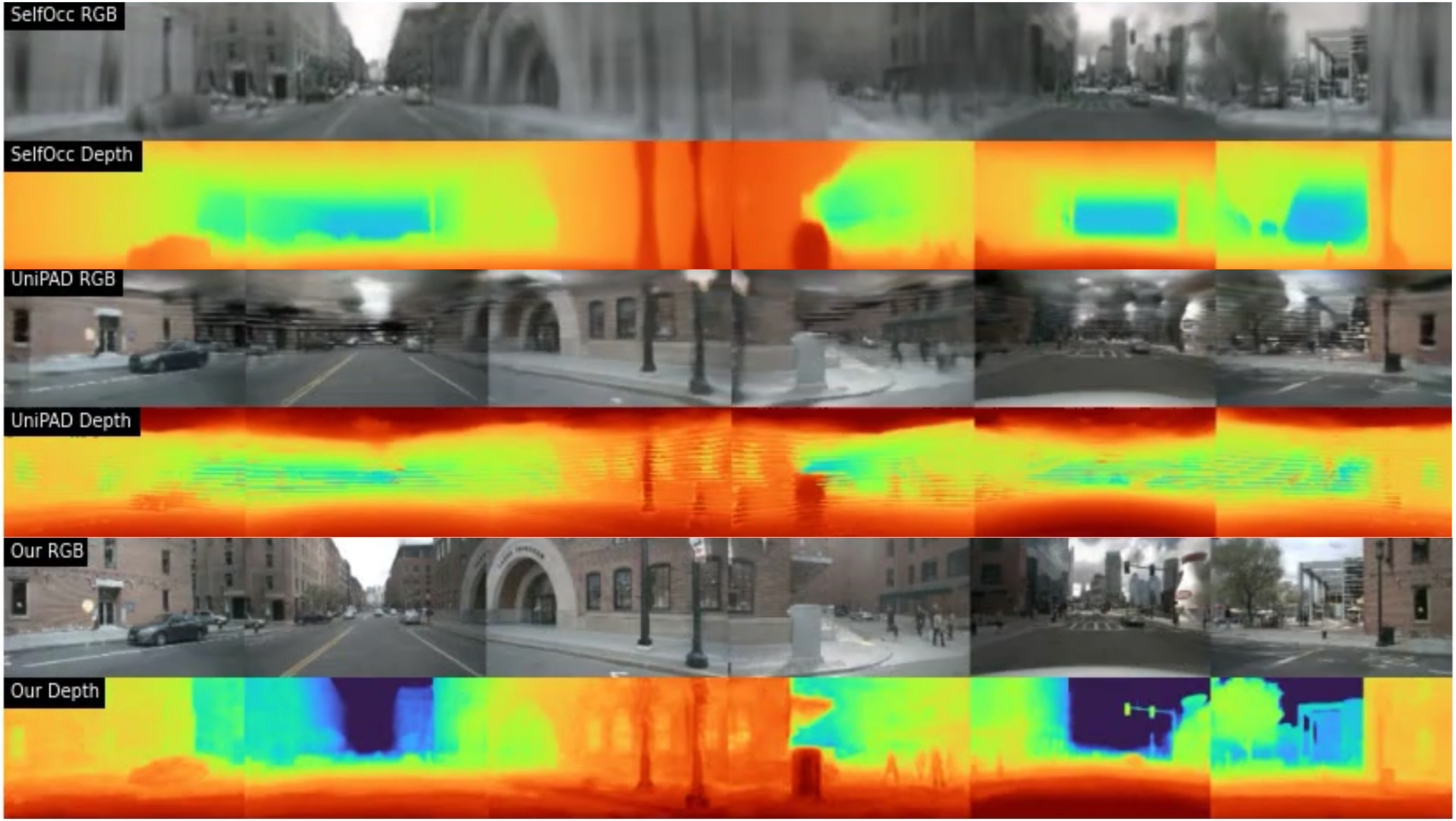


Generalization: Trained on nuScenes, strong generalized performance on the unseen Waymo dataset

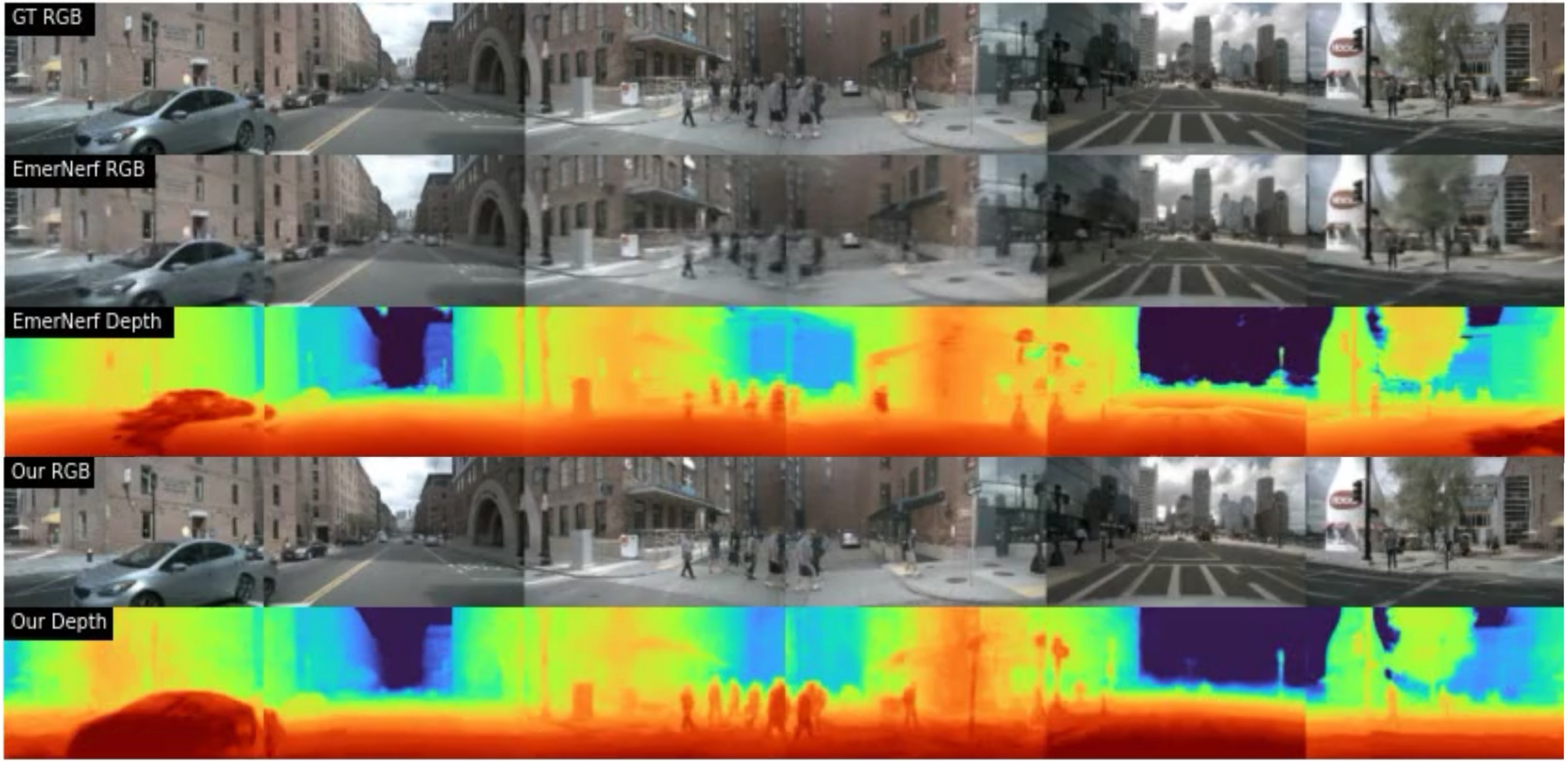


Row 2: zero-shot transfer with decent reconstruction quality
Row 3: enhanced quality via simple color alterations to account for camera-specific coloring effects
Row 4: after fine-tuning, our model surpasses the SOTA per-scene EmerNeRF in the reconstruction quality

Comparison: Significantly outperform SOTA generalizable NeRF methods in driving scenes



Comparison: On-par with SOTA per-scene optimized NeRF in driving scenes (EmerNeRF)



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