# 3D Shape Reconstruction from Autonomous Driving Radars

Samah Hussein[1] Junfeng Guan[1,3] Swathi Shree Narashiman[1]
Saurabh Gupta[2] Haitham Hassanieh[1]
[1]EPFL [2]UIUC [3]Bosch Research

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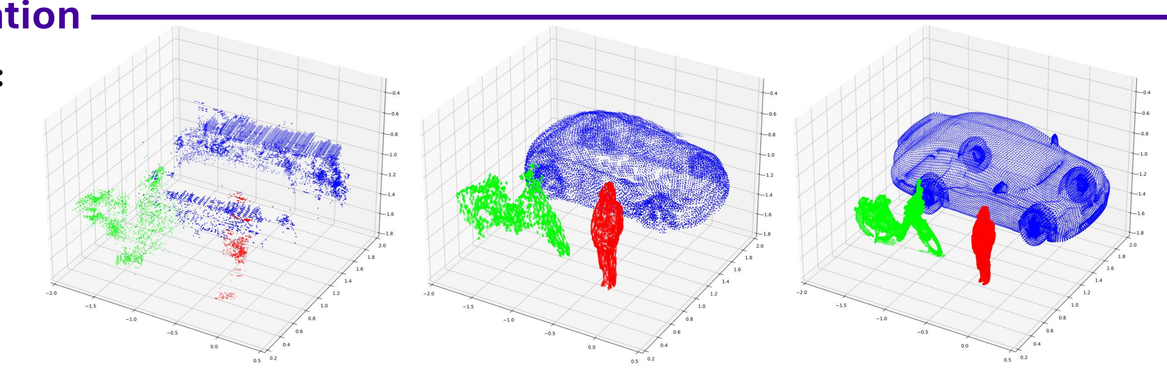
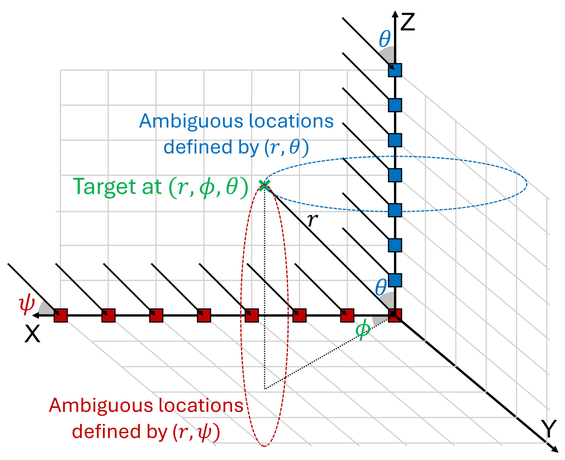
## Motivation

| | Visual sensors: | mmWave radars: |
|---|---|---|
| Works in poor visibility (fog, rain, dark) | ❌ | ✅ |
| Unaffected by fog, rain, or snow | ❌ | ✅ |
| Robustness to occlusions | ❌ | ✅ |
| High 3D spatial resolution | ✅ | ❌ |
| Robust to specular surfaces | ✅ | ❌ |

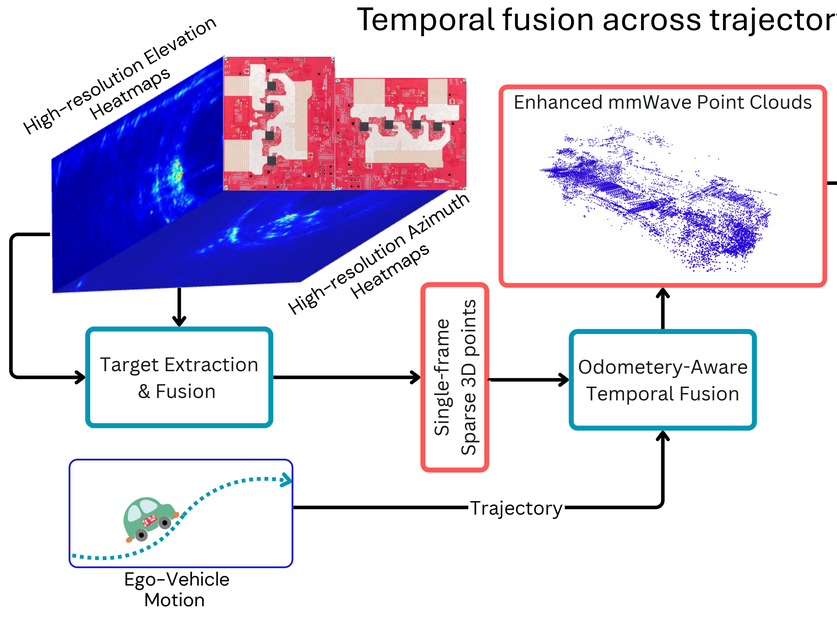



## RFConstruct Overview

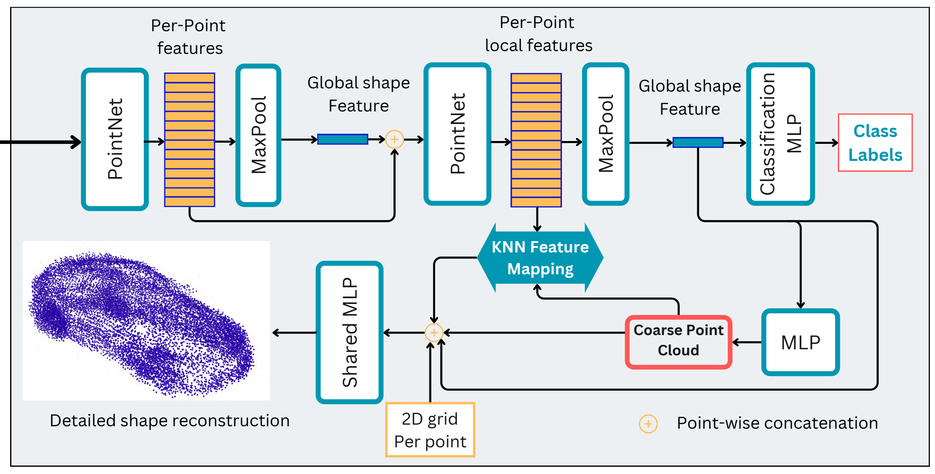
**Enhancing Spatial resolution:**
Combining two 1D antenna arrays deployed orthogonally




**Combating Specular reflections:**
Temporal fusion across trajectory




**Partial Shape Observations:**
Shape completion network

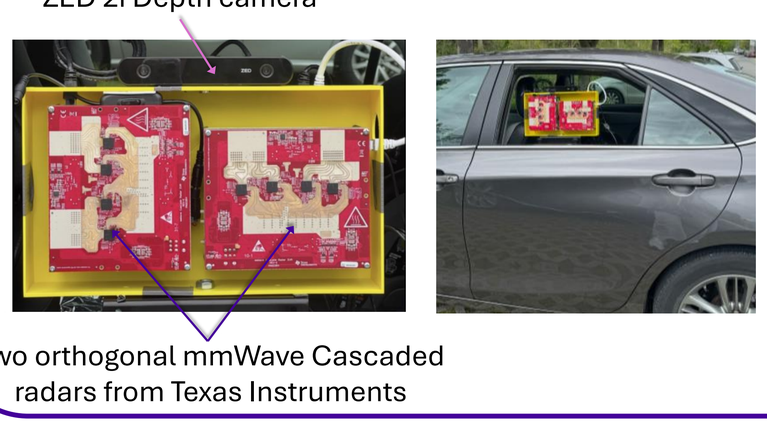



## Dataset

RFConstruct is **trained on a synthetic dataset** extracted from ShapeNet[2] and CAESAR[3] to resemble radar data via two methods:
- Augmenting parital shape point clouds with noise and cropped portions to **emulate signal specularity**
- Simlating radar signals using a **mmwave radar simulator** introduced in [1]

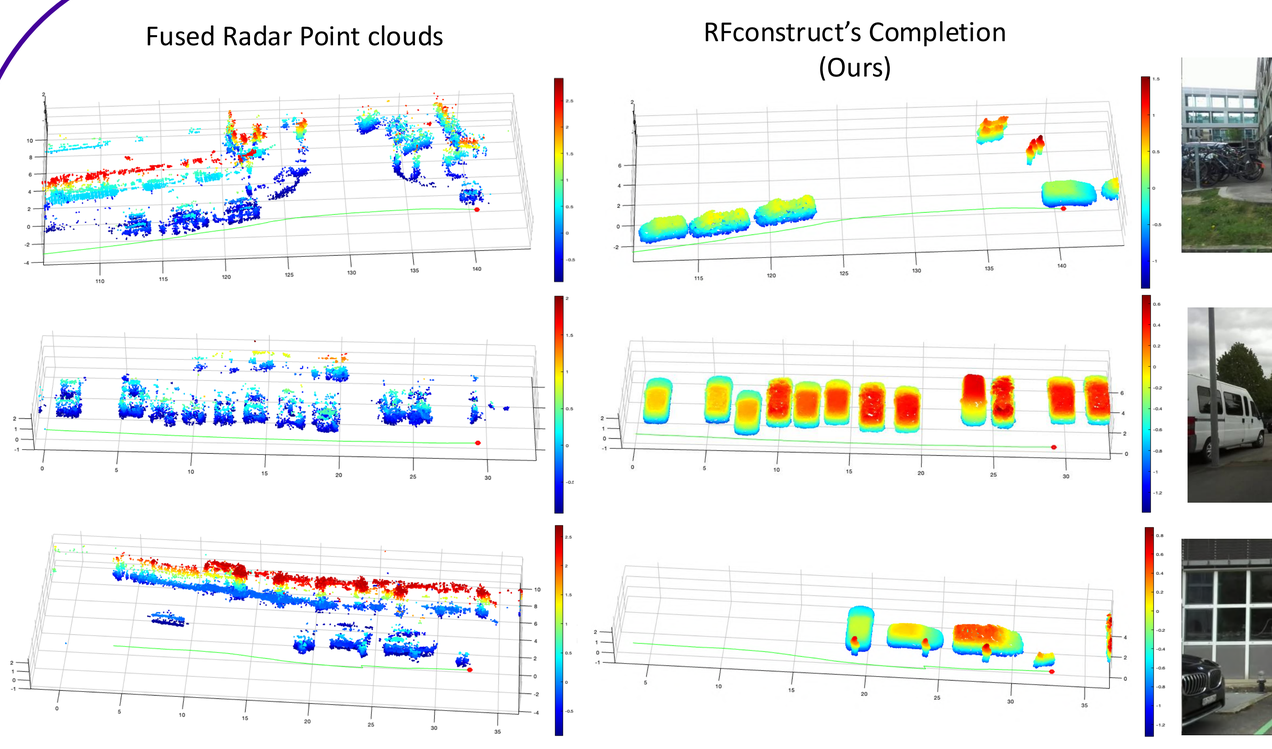
RFConstruct is then **fine-tuned using real data** collected with our setup for the classes of objects most prominent in self-driving scenarios: Cars, Humans, Bikes, Motorbikes. This data includes **162 cars, 91 bikes, and 52 humans** as point clouds.

## Experimental Setup




In our simulations, data collection, and evaluation, we ensure that the trajectory resembles natural driving scenarios where mostly one side of an object is briefly captured as the Ego-Vehicle is passing by.

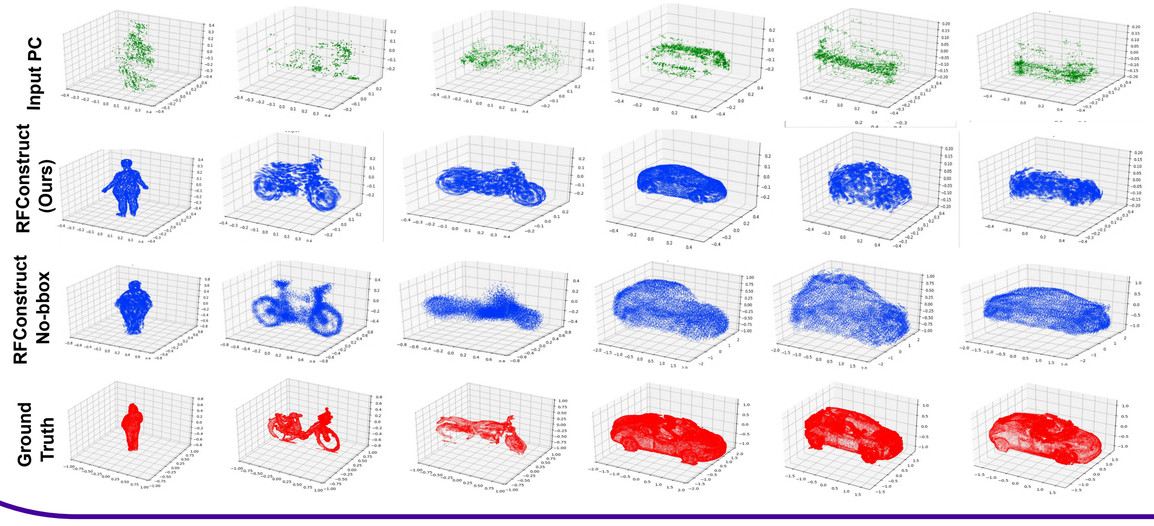
## Results & baselines




**Metrics:** Chamfer Distance (CD)
Earth Mover's Distance (EMD)

| With Bounding-box Priors | | |
|---|---|---|
| | **Mean CD** | **Mean EMD** |
| ODGNet | 3.89 | 16.07 |
| AdaPointTr | 3.42 | 14.94 |
| PCN | 4.58 | 13.03 |
| Medoid Baseline | 2.52 | 9.16 |
| RFconstruct | 3.52 | 11.7 |
| **Fine-tuned RFconstruct** | ***2.01*** | ***6.25*** |

| Without Bounding-box Priors | | |
|---|---|---|
| | **Mean CD** | **Mean EMD** |
| ODGNet | 52.2 | 108 |
| AdaPointTr | 43 | 91.46 |
| PCN | 42.1 | 90.8 |
| Medoid Baseline | N/A | N/A |
| RFconstruct | 28.8 | 82.7 |
| Fine-tuned RFconstruct | **15.3** | **49.9** |




**Check out the project Website!**

**Check out RFConstruct Demo!**

[1] Guan, J., Madani, S., Jog, S., Gupta, S., & Hassanieh, H. (2020). Through Fog High-Resolution Imaging Using Millimeter Wave Radar. In *IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*.
[2] Chang, A., Funkhouser, T., Guibas, L., Hanrahan, P., Huang, Q., Li, Z., Savarese, S., Savva, M., Song, S., Su, H., Xiao, J., Yi, L., & Yu, F. (2015). *ShapeNet: An Information-Rich 3D Model Repository* [White paper]. Stanford University –- Princeton University –- Toyota Technological Institute at Chicago.
[3] Yipin Yang, Yao Yu, Yu Zhou, Sidan Du, James Davis, and Ruigang Yang. Semantic parametric reshaping of human body models. *In 2014 2nd International Conference on 3D Vision*.