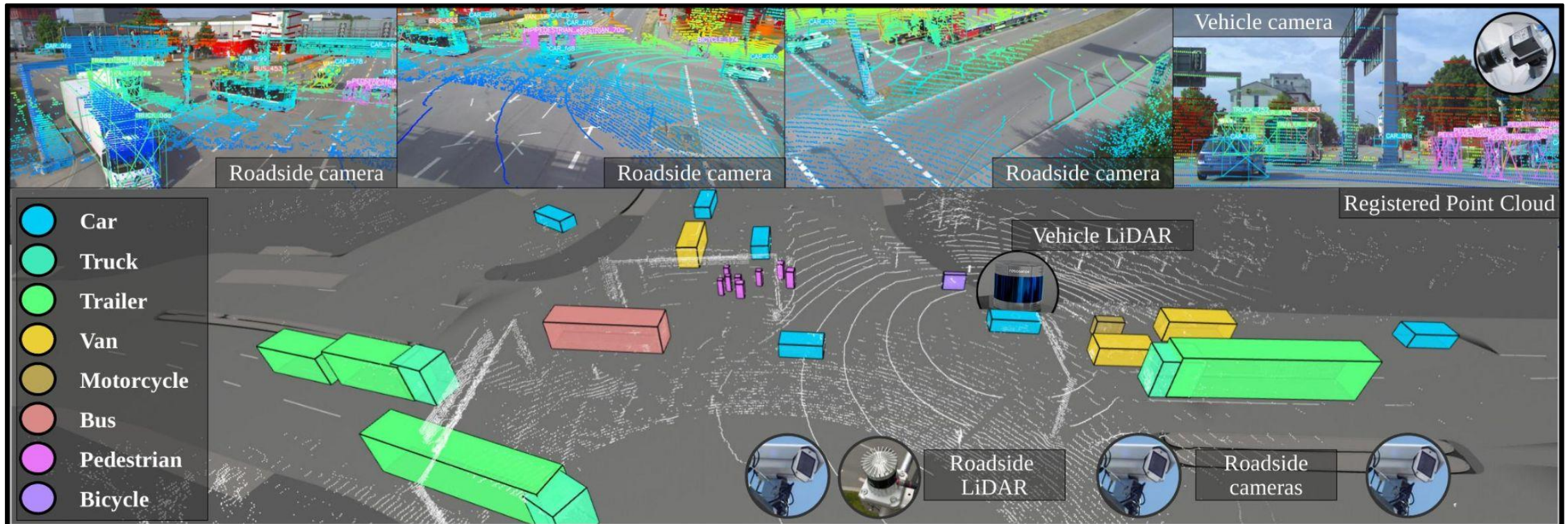


IEEE/CVF Computer Vision and Pattern Recognition 2024 (CVPR'24)

# TUMTraf V2X Cooperative Perception Dataset

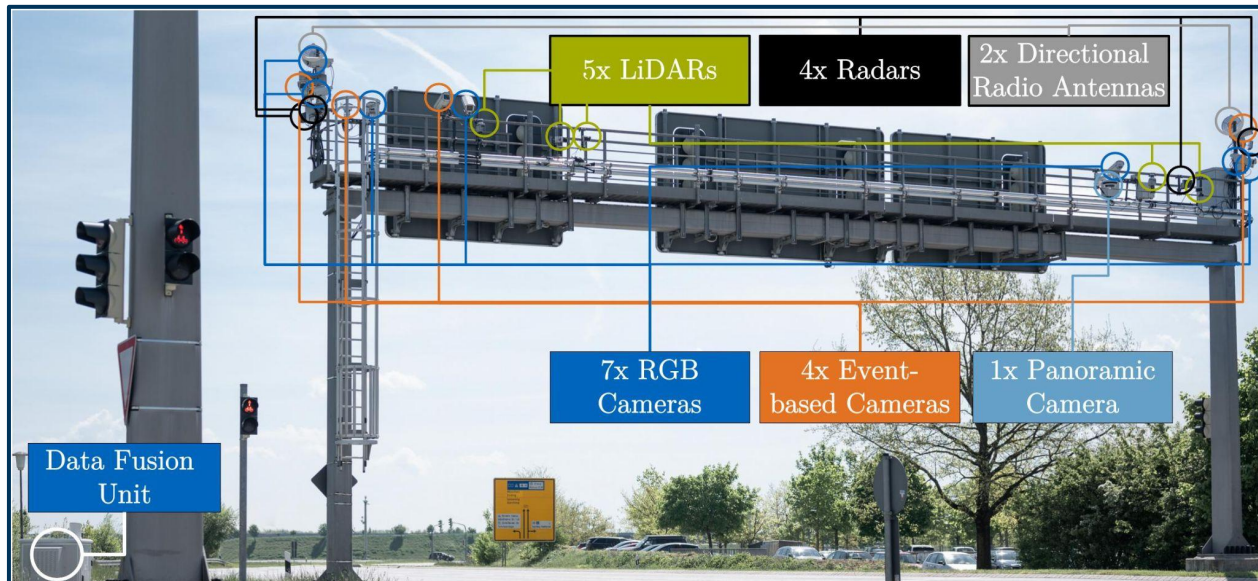
Walter Zimmer<sup>1</sup>, Gerhard Arya Wardana<sup>1</sup>, Suren Sritharan<sup>1</sup>, Xingcheng Zhou<sup>1</sup>, Rui Song<sup>1,2</sup>, Alois C. Knoll<sup>1</sup>  
<sup>1</sup> Technical University of Munich, <sup>2</sup> Fraunhofer IVI



# Motivation

Roadside view expands visibility range

Occlusions are reduced



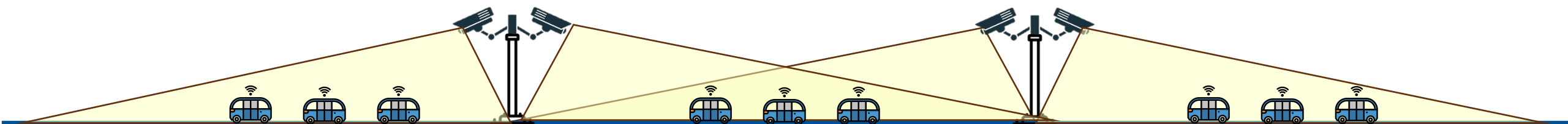
A9 Digital Testbed

TUM Traffic Dataset

TUMTraf-V2X Dataset

Digital Twin of traffic

Automated Driving Level 4



# Motivation

Table 1. Comparison of 3D cooperative V2X perception datasets with our proposed TUMTraf-V2X Cooperative Perception dataset (I=Infrastructure, V=Vehicle).

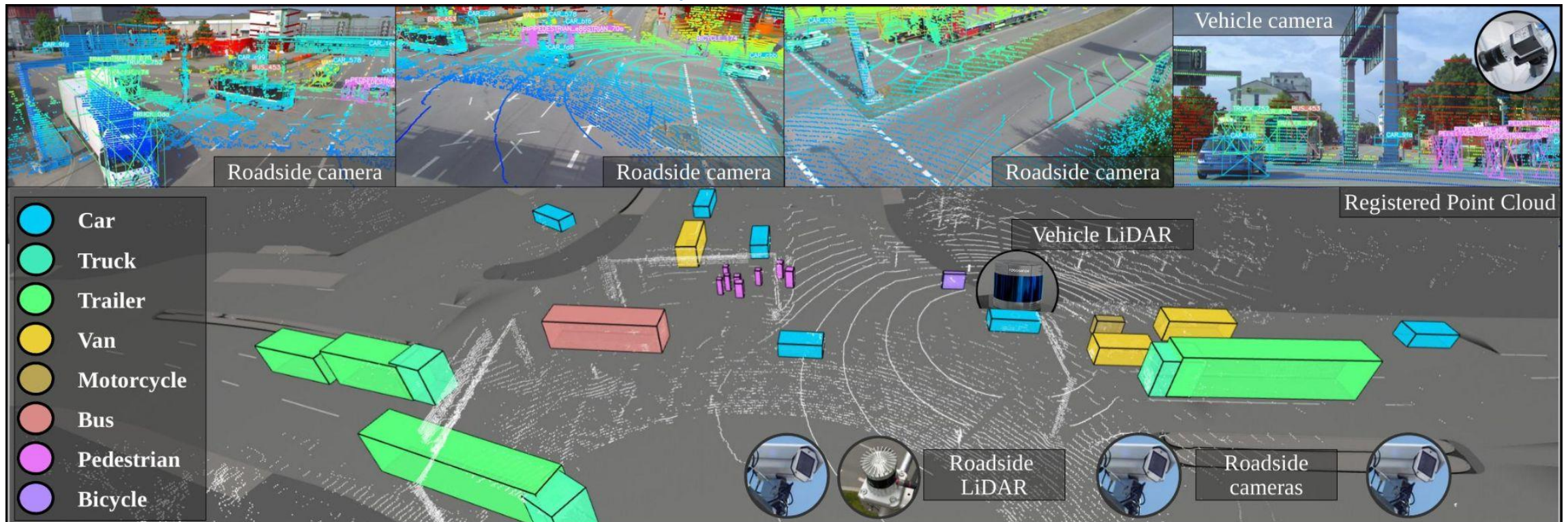
Dataset	OPV2V [51]	V2XSet [49]	V2X-Sim [30]	V2V4Real [52]	DAIR-V2X- C [57]	V2X-Seq (SPD) [59]	<b>TUMTraf- V2X (Ours)</b>
Year	2022	2022	2022	2022	2022	2023	2024
V2X	V2V	V2V&I	V2V&I	V2V	V2I	V2I	V2I
Real data	-	-	-	✓	✓	✓	✓
Annotation range	120 m	120 m	70 m	200 m	280 m	280 m	200 m
Day & night scenes	-	-	-	-	✓	✓	✓
# object classes	1	1	1	5	10	9	8
Track IDs	-	-	✓	✓	-	✓	✓
HD Maps	✓	✓	✓	✓	-	✓	✓
# of sensors (I   V)	-   6*	-   6*	5   7	-   8 <sup>‡</sup>	2   3	2   3	5   4
Available worldwide	✓	✓	✓	✓	-	-	✓
Traffic violations	-	-	-	-	-	-	✓
Labeled attributes <sup>#</sup>	-	-	-	-	-	-	✓
OpenLABEL format	-	-	-	-	-	-	✓
# Point Clouds	11k	11k	10k	20k	39k	15k	2.0k
# Images	44k	44k	60k	40k <sup>†</sup>	39k	15k	5.0k
# 3D Boxes	233k	233k	26k	240k	464k	10.45k	29.38k
Location	CARLA	CARLA	CARLA	USA	China	China	Germany

<sup>†</sup> Image dataset has not been released yet.

<sup>‡</sup> Total sensors from 2 CAVs.

\* Value per vehicle. Multiple Conn. and Autom. Vehicles (CAVs) are used. <sup>#</sup> Weather, time of day, orientation, number of LiDAR points

# TUM Traffic Cooperative V2X Dataset



2,000 labeled point clouds

30k tracked 3D boxes

Vehicle & roadside sensors

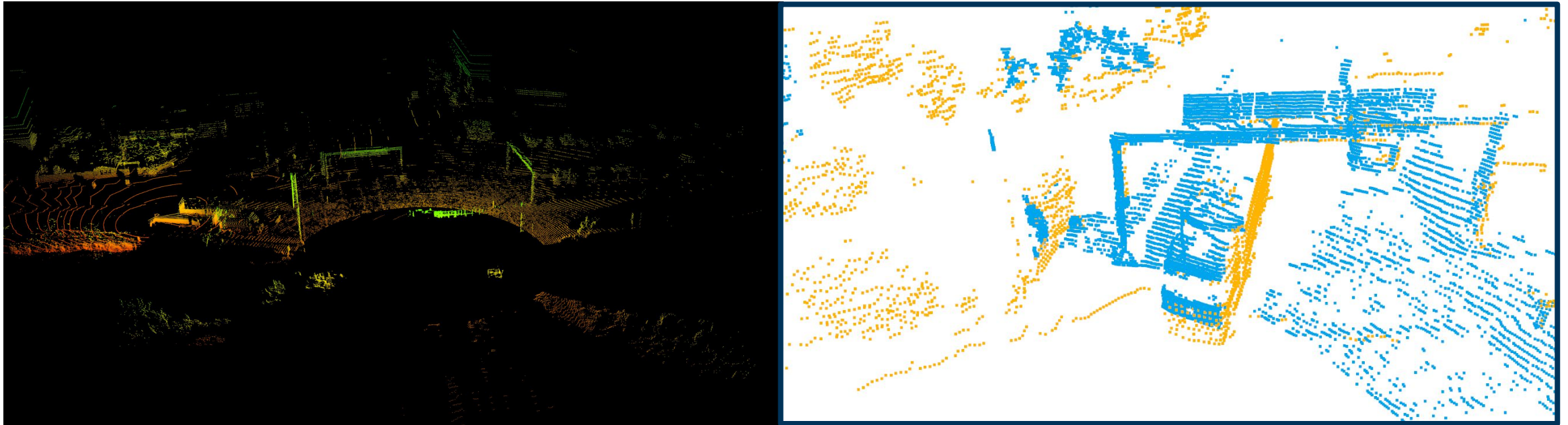
5,000 labeled images

Traffic violation events

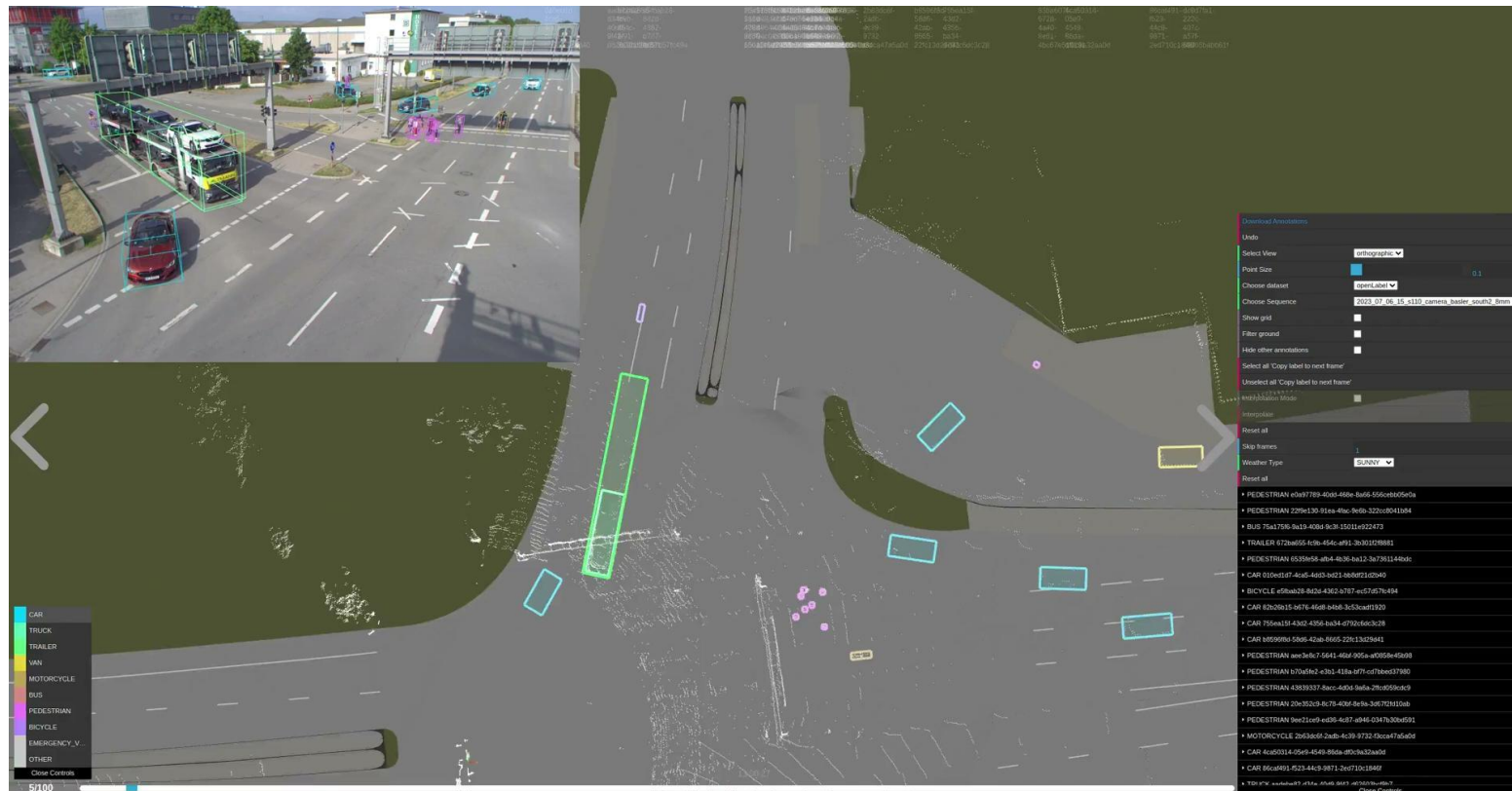
Day and night data

# Dataset Curation

## Point Cloud Registration



# Dataset Curation Labeling



3D BAT labeling tool

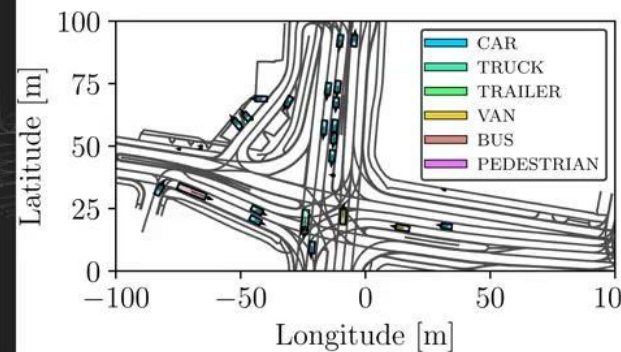
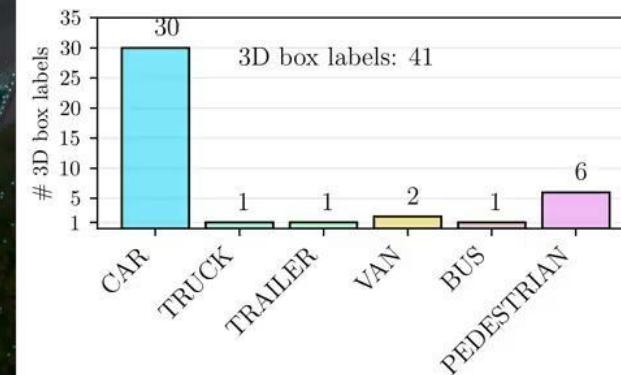
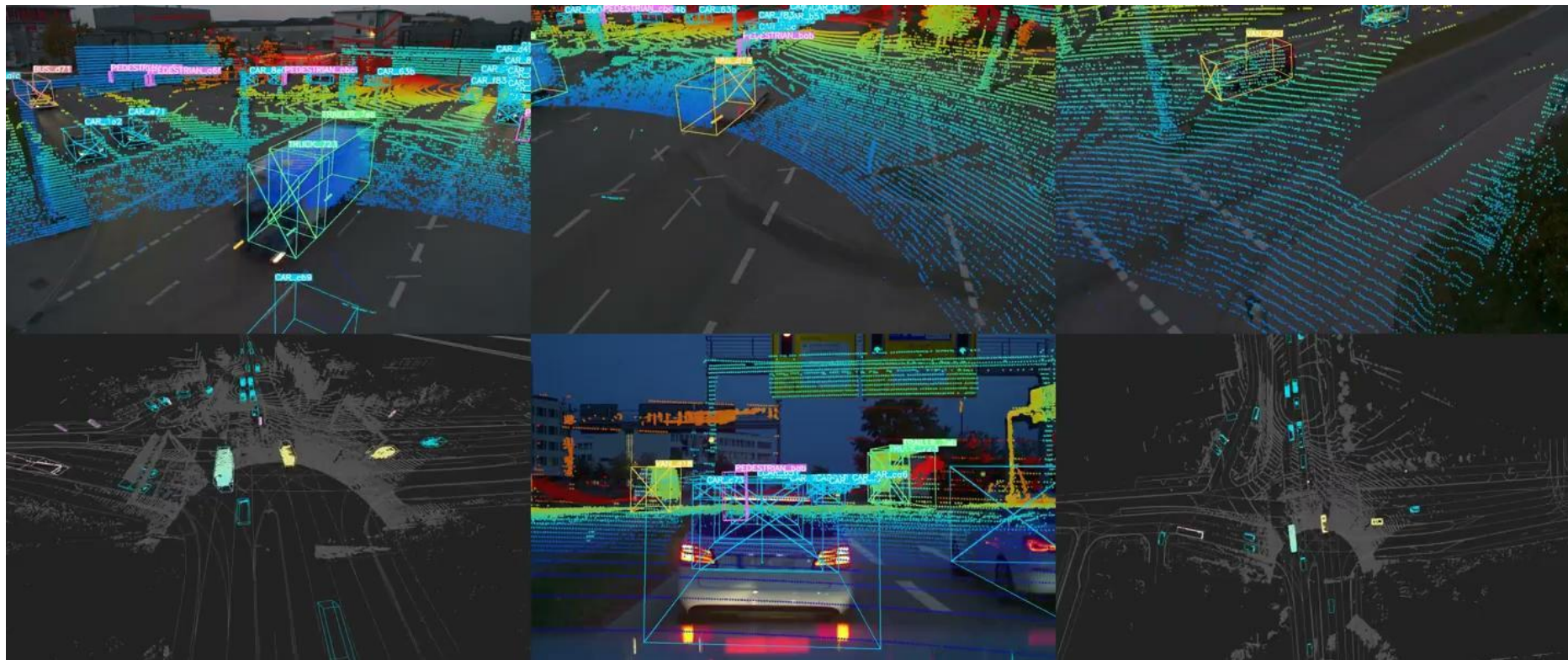
One-click annotation

# TUM Traffic Cooperative V2X Dataset

Visualization of drive 15 sequence

More videos on:  
[tum-traffic-dataset.github.io/tumtraf-v2x](https://tum-traffic-dataset.github.io/tumtraf-v2x)

# TUM Traffic Cooperative V2X Dataset

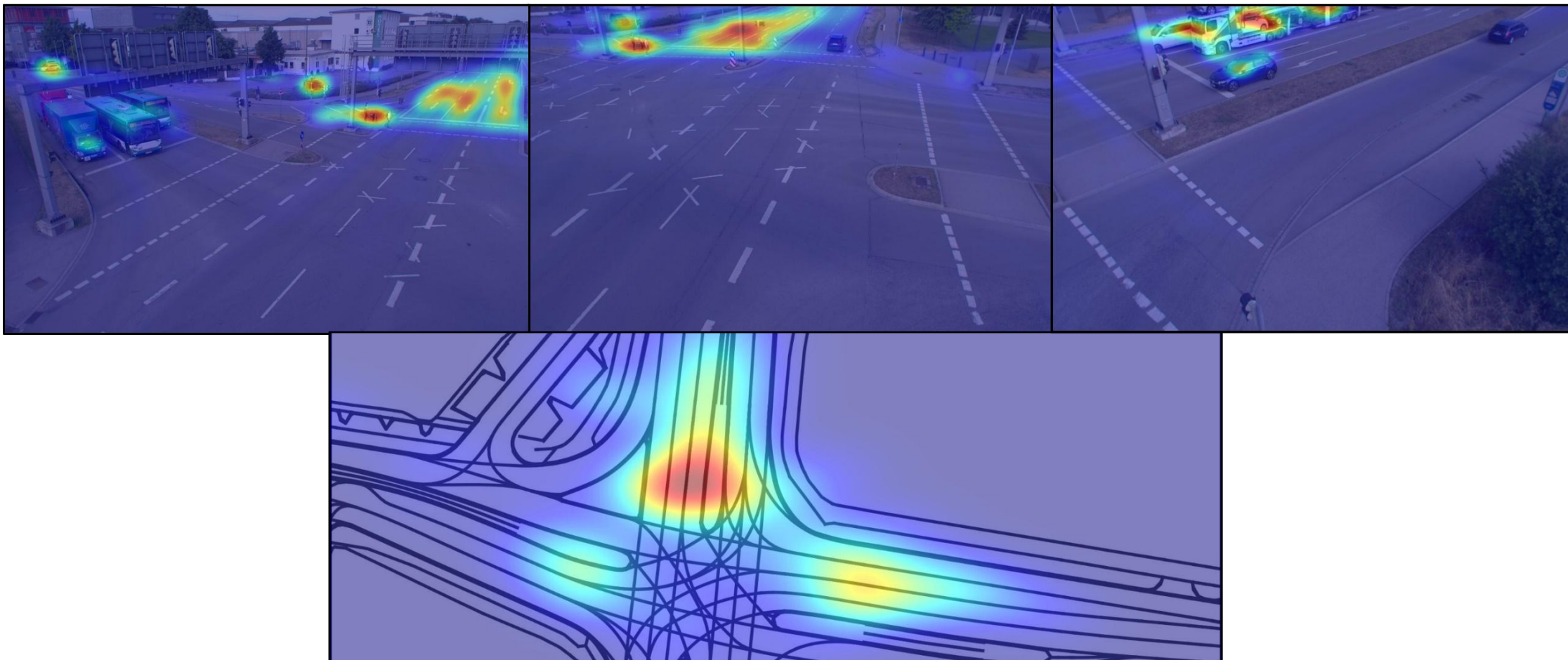


Visualization of drive 42 sequence

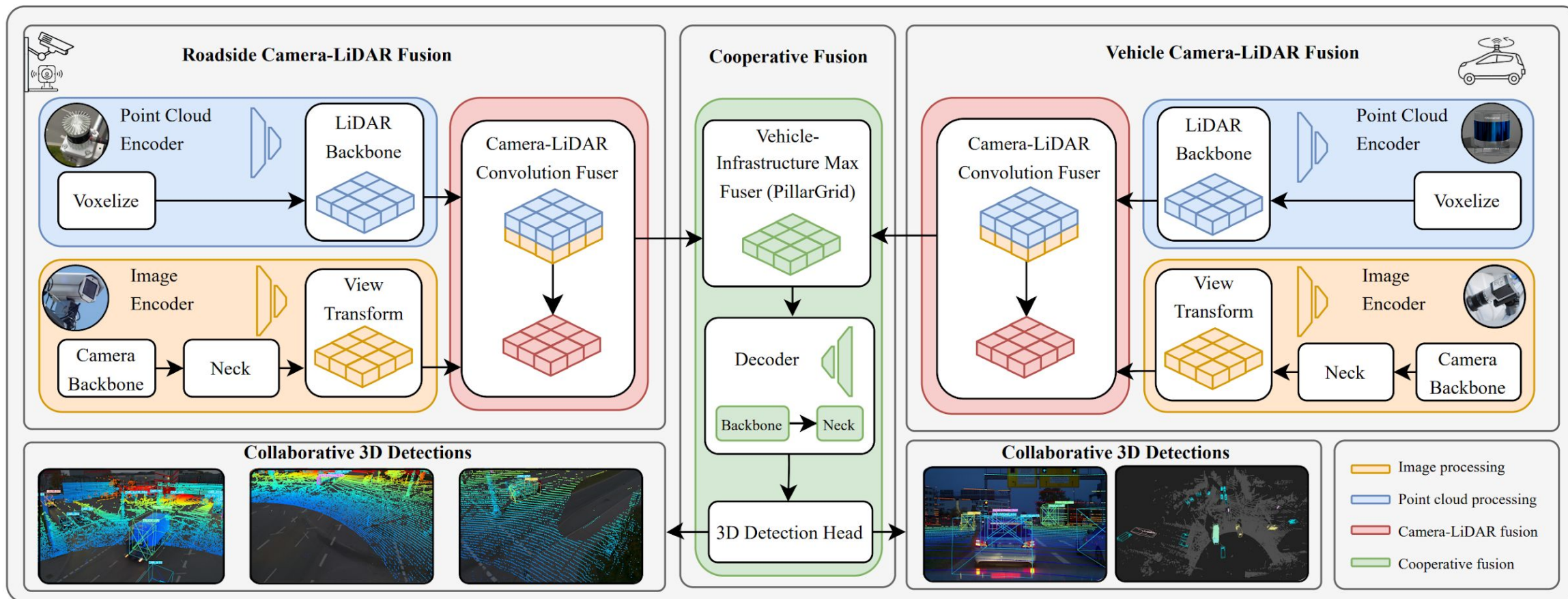
More videos on:  
[tum-traffic-dataset.github.io/tumtraf-v2x](https://tum-traffic-dataset.github.io/tumtraf-v2x)



# TUM Traffic Cooperative V2X Dataset

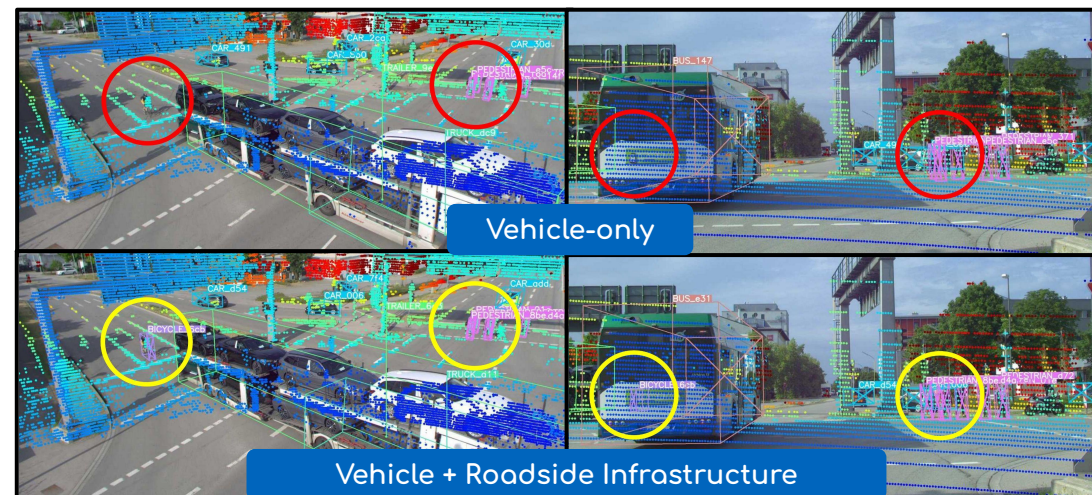


# Cooperative Camera+LiDAR 3D Perception Architecture



# Cooperative Camera+LiDAR 3D Perception Evaluation

Domain	Config. Modality	mAP <sub>BEV</sub> ↑		mAP <sub>3D</sub> ↑		
		Easy↑	Modality↑	Hard↑	Avg.↑	
Vehicle	Camera	46.83	31.47	37.82	30.77	30.36
Vehicle	LiDAR	85.33	85.22	76.86	69.04	80.11
Vehicle	Cam+LiDAR	84.90	77.60	72.08	73.12	76.40
Infra.	Camera	61.98	31.19	46.73	40.42	35.04
Infra.	LiDAR	92.86	86.17	88.07	75.73	84.88
Infra.	Cam+LiDAR	92.92	87.99	<b>89.09</b>	<b>81.69</b>	87.01
Coop.	Camera	68.94	45.41	42.76	57.83	45.74
Coop.	LiDAR	93.93	92.63	78.06	73.95	85.86
Coop.	Cam+LiDAR	<b>94.22</b>	<b>93.42</b>	88.17	79.94	<b>90.76</b>



Evaluation results of CoopDet3D on TUM Traffic Cooperative V2X test set

Baseline BEVFusion

- Vehicle cam.+LiDAR: 76.40 mAP
- Infrastr. cam.+LiDAR: 87.01 mAP

Results

- CoopDet3D model: 90.76 mAP

# Cooperative Camera+LiDAR 3D Perception Evaluation

Config.	FOV <sup>3</sup>	Mod.	mAP <sub>3D</sub> ↑			
			Easy ↑	Mod. ↑	Hard ↑	Avg. ↑
InfraDet3D	south 1	LiDAR	75.81	47.66	<b>42.16</b>	55.21
CoopDet3D	south 1	LiDAR	<b>76.24</b>	<b>48.23</b>	35.19	<b>69.47</b>
InfraDet3D	south 2	LiDAR	38.92	46.60	<b>43.86</b>	43.13
CoopDet3D	south 2	LiDAR	<b>74.97</b>	<b>55.55</b>	39.96	<b>69.94</b>
InfraDet3D	south 1	Cam+LiDAR	67.08	31.38	35.17	44.55
CoopDet3D	south 1	Cam+LiDAR	<b>75.68</b>	<b>45.63</b>	<b>45.63</b>	<b>66.75</b>
InfraDet3D	south 2	Cam+LiDAR	58.38	19.73	33.08	37.06
CoopDet3D	south 2	Cam+LiDAR	<b>74.73</b>	<b>53.46</b>	<b>41.96</b>	<b>66.89</b>



Evaluation results of CoopDet3D vs. InfraDet3D  
on TUM Traffic Intersection test set

# Team

**CVPR SEATTLE, WA JUNE 17-21, 2024**  
**Poster Session 5:**  
 When? June 21, 2024 10:30 - 12:00  
 Where? Exhibit Hall Arch 4A-E



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