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上海人工智能实验室
Shanghai Artificial Intelligence Laboratory

OpenLane-V2: A Topology Reasoning Benchmark for Unified 3D HD Mapping

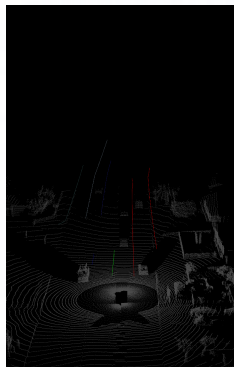
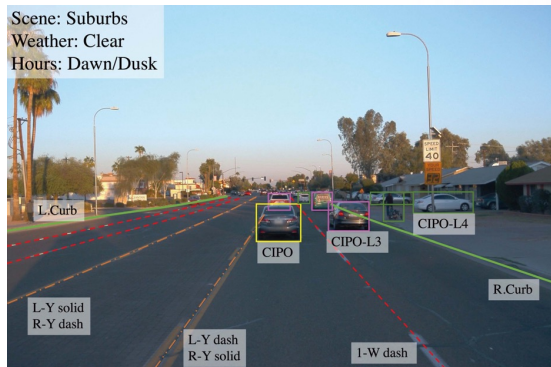
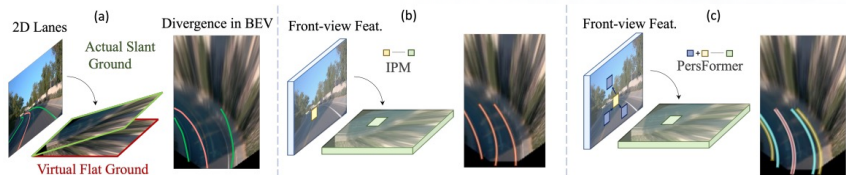
Huijie Wang*, Tianyu Li*, Yang Li*, Li Chen, Chonghao Sima, Zhenbo Liu, Bangjun Wang, Peijin Jia, Yuting Wang, Shengyin Jiang, Feng Wen, Hang Xu, Ping Luo, Junchi Yan, Wei Zhang, Hongyang Li

OpenDriveLab, Shanghai AI Lab | Huawei Noah's Ark Lab

NeurIPS 2023

OpenLane-V2 <https://github.com/OpenDriveLab/OpenLane-V2>

OpenLane



Mapping



OpenLane-V2 <https://github.com/OpenDriveLab/OpenLane-V2>

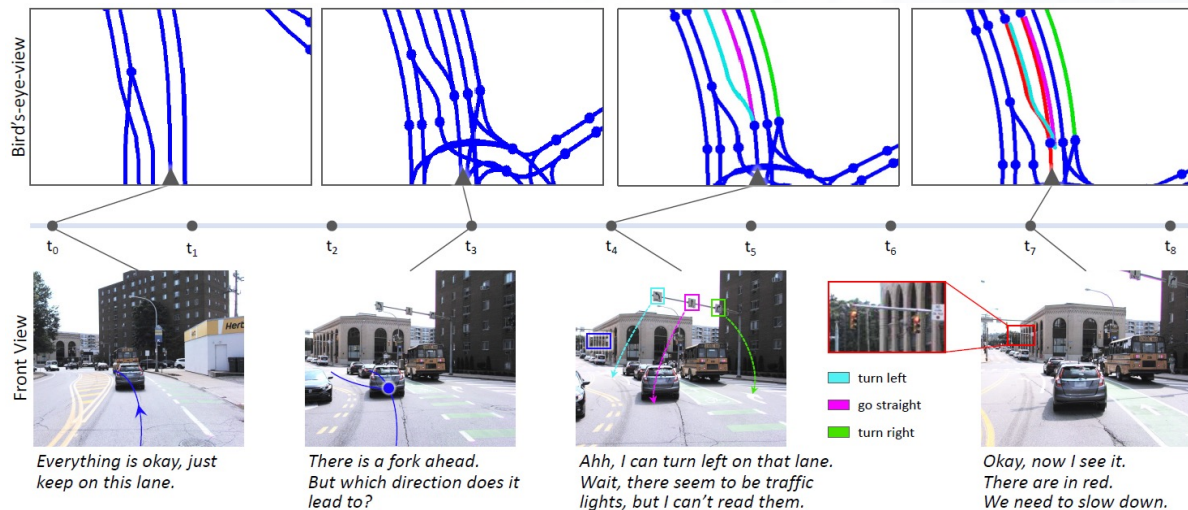
Area without Laneline



Traffic Element



Overview



- Centerlines
- Topology between Centerlines and Traffic Elements
- Traffic Elements on Front-view Images
- Topology between Centerlines

Statistics

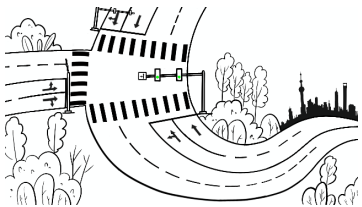
Split	<i>subset_A</i>			<i>subset_B</i>		
	Train	Val	Test	Train	Val	Test
Sample Rate	$2Hz$					
Annotation Range	$\pm 50m$ (x-axis), $\pm 25m$ (y-axis)					
# Camera	7			6		
Image Resolution	$2048 \times 1550^*$			1600×900		
Avg. Duration of Scene Segments	15s			20s		
# Scene Segment	700	150	150	700	150	150
Avg. # Centerline per Frame	26.34	26.44	26.50	24.32	24.80	23.82
Avg. # Traffic Element per Frame	3.70	3.69	2.80	3.58	3.76	3.25
Avg. # Connection per Centerline	1.90	1.89	1.89	1.83	1.79	1.84
Avg. # Corresponded Centerline per Traffic Element	0.71	0.83	0.91	0.54	0.52	0.58

- **Subset_A** includes Austin, Detroit, Miami, Pittsburgh, Palo Alto, and Washington D.C.
- **Subset_B** includes Boston and Singapore

Task and Evaluation

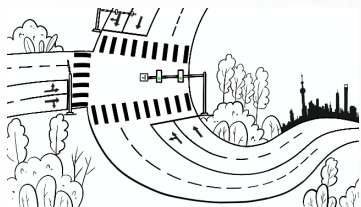
$$\text{OLS} = \frac{1}{4} \left[\text{DET}_l + \text{DET}_t + f(\text{TOP}_{ll}) + f(\text{TOP}_{lt}) \right]$$

3D Lane Detection



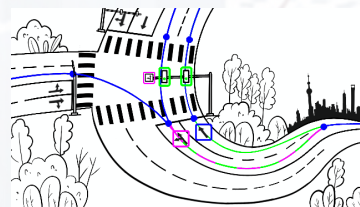
$$\text{DET}_l = \frac{1}{|\mathbb{T}|} \sum_{t \in \mathbb{T}} AP_t$$

Traffic Element Recognition



$$\text{DET}_t = \frac{1}{|\mathbb{A}|} \sum_{a \in \mathbb{A}} AP_a$$

Topology Recognition LCLC

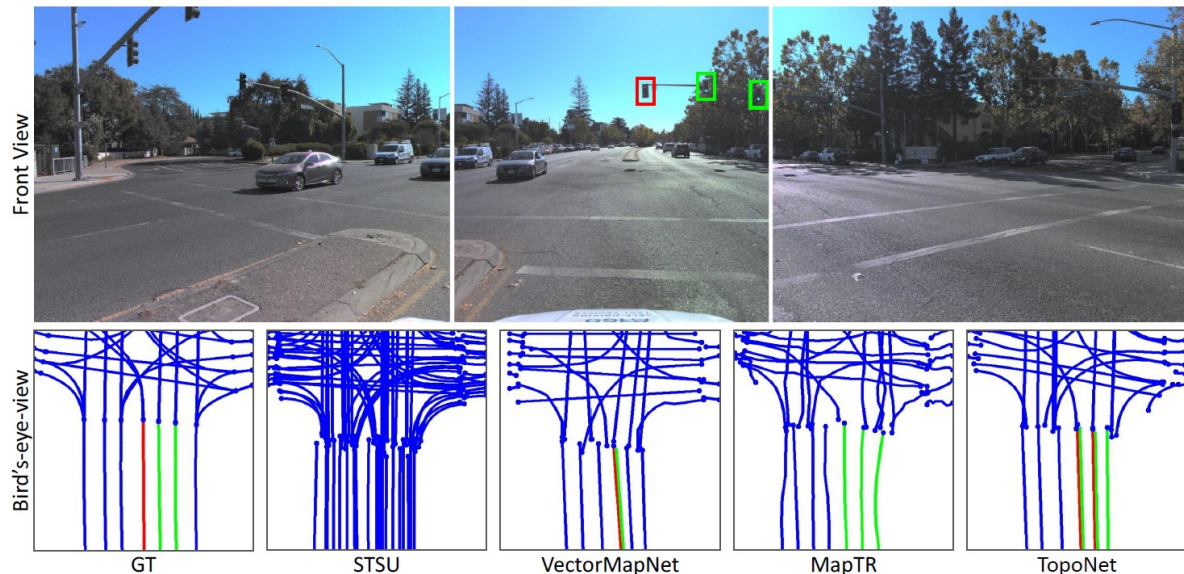


$$\text{TOP} = \frac{1}{|V|} \sum_{v \in V} \frac{\sum_{\hat{n}' \in \hat{N}'(v)} P(\hat{n}') \mathbb{1}(\hat{n}' \in N(v))}{|N(v)|}$$

Topology Recognition LCTE

OpenLane-V2 <https://github.com/OpenDriveLab/OpenLane-V2>

Experiments



Method	Design	<i>subset_A</i>				
		OLS	DET _l	DET _t	TOP _{ll}	TOP _{lt}
STSU [6]	Instance	25.4	12.7	43.0	0.5	15.1
VectorMapNet [28]	Point Set	20.8	11.1	41.7	0.4	5.9
MapTR [27]	Point Set	20.0	8.3	43.5	0.2	5.9
TopoNet [26]	Instance	35.4	29.2	48.0	4.1	19.3

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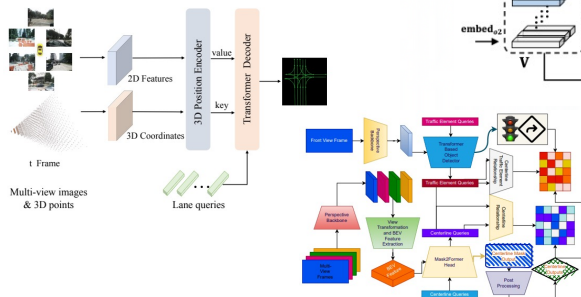


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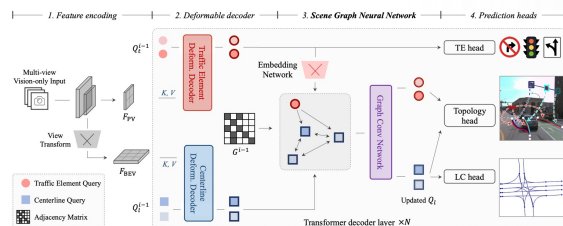
OpenLane Topology Challenge @ CVPR 2023

AD Challenge - 2023 <https://opendriveLab.com/AD23Challenge.html> | <https://eval.ai/web/challenges/challenge-page/1925>

OpenLane Topology

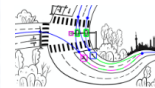


TopoNet



<https://github.com/OpenDriveLab/TopoNet>

[arXiv: 2304.05277](https://arxiv.org/abs/2304.05277)



OpenLane Topology Challenge

Organized by: [OpenDriveLab](#)

Published

Starts on: Jan 16, 2023 12:00:00 AM +08 (GMT + 8:00)

Ends on: Feb 16, 2099 12:00:00 AM +08 (GMT + 8:00)

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Rank	Participant team	DET_I (1)	DET_t (1)	TOP_IJ (1)	TOP_IJt (1)	OLS (1)	F-Score (1)	Last submission at	
1	MFV		0.3577	0.7970	0.2252	0.3348	0.5519	0.2559	5 months ago
2	qcraft2		0.4168	0.6374	0.0657	0.3037	0.4654	0.4805	5 months ago
3	Victory		0.2184	0.7245	0.1324	0.2261	0.4456	0.2530	5 months ago
4	PlatypusWhisperers		0.2209	0.7061	0.0602	0.1570	0.3922	0.4592	5 months ago
5	MT_gavin		0.1790	0.7028	0.0401	0.2112	0.3854	0.2478	5 months ago
6	qwertyczx (e110_J)		0.2643	0.6607	0.0317	0.1918	0.3853	0.2817	5 months ago
7	turing-machine		0.1335	0.7864	0.0148	0.1266	0.3493	0.2494	5 months ago
8	Haoqing		0.0863	0.7187	0.0369	0.1516	0.3466	0.4019	5 months ago
9	TopoNet-Anonymous		0.1950	0.5842	0.0227	0.1591	0.3322	0.2757	5 months ago
10	BVLab		0.1235	0.6416	0.0253	0.1558	0.3297	0.2700	5 months ago
11	HDI_EasternExpo		0.1389	0.6367	0.0130	0.1546	0.3207	0.1998	5 months ago
12	ArterySentinel		0.1182	0.4459	0.0008	0.0286	0.1904	0.2175	5 months ago
13	WeakChicken		0.0000	0.6772	0.0000	0.0000	0.1695	0.0000	7 months ago

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Toward 2024

Datasets <https://github.com/OpenDriveLab/DriveAGI>

OpenLane-V2 Update

Map Element Bucket. We provide a diverse span of road elements (as a bucket) to build the driving scene - on par with all elements in HD Map.



Standard-definition (SD) Map. As a new sensor input, SD Map supplements multi-view images with topological and positional priors to strengthen structural acknowledge in the neural networks.



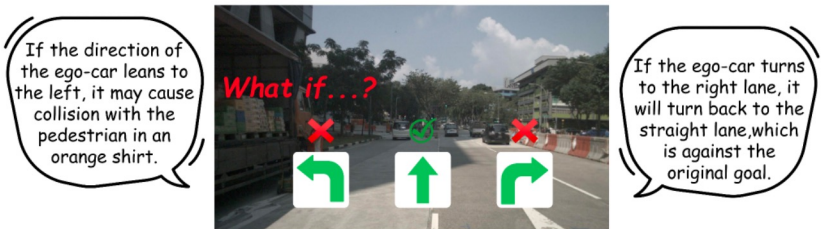
Datasets <https://github.com/OpenDriveLab/DriveAGI>

DriveLM

Completeness in functionality (covering Perception, Prediction and Planning QA pairs).

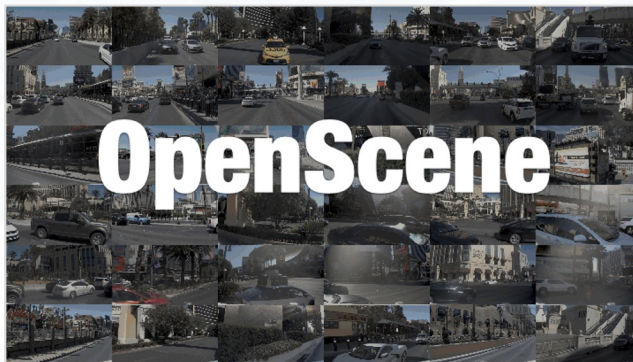


Reasoning for future events that have not yet happened. Many "What If"-style questions: imagine the future by language.



OpenScene

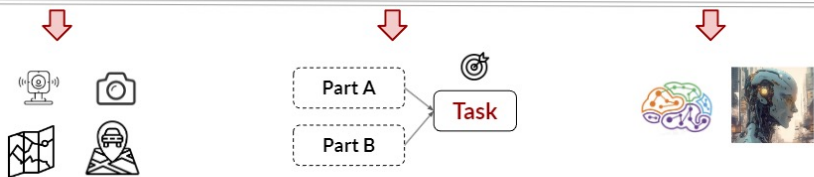
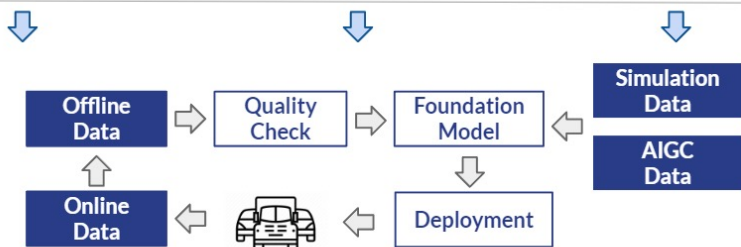
The Largest Benchmark for 3D Occupancy Prediction



Dataset	Original Database	Sensor Data (hr)	Flow	Semantic Category
MonoScene	NYUv2 / SemanticKITTI	5 / 6	✗	10 / 19
Occ3D	nuScenes / Waymo	5.5 / 5.7	✗	16 / 14
Occupancy-for-nuScenes	nuScenes	5.5	✗	16
SurroundOcc	nuScenes	5.5	✗	16
OpenOccupancy	nuScenes	5.5	✗	16
SSCBench	KITTI-360 / nuScenes / Waymo	1.8 / 4.7 / 5.6	✗	19 / 16 / 14
OccNet	nuScenes	5.5	✗	16
OpenScene	nuPlan	120	✓	7000

Open-sourced Data Ecosystem in Autonomous Driving

DOI: 10.13140/RG.2.2.10945.74088



Dataset	Year	Data Diversity			Sensor	LIDAR	Sensor	Annotation	Impact
		Scenes	Frames	Regions					
ADFF [97]	2012	96	6	EU	Front-view	✓	GPS & IMU	3D Bbox, AOB Bbox	High
Cityscapes [23]	2016	-	-	EU	Front-view	✓	-	2D Seg	Mid
Leak and Front [60]	2016	112	-	EU	Front-view	✓	-	2D Seg	Mid
Mapillary [9]	2016	-	-	Global	Street-view	✓	-	2D Seg	Mid
IMDUT [31]	2017	26	12	EU	Front-view	✓	GPS & CAN-bus & Event Camera	3D Bbox & 2D Seg	Mid
Apollonix [26]	2016	303	2.5	AS	Front-view	✓	GPS & IMU	3D Bbox & 2D Seg	Mid
ISU [36]	2018	694	77	EU	Front-view	✓	-	Language	Mid
HOLO [38]	2018	152	104	NA	Front-view	✓	GPS & IMU & CAN-bus	2D Bbox	Mid
ISU [36]	2018	152	104	EU	Front-view	✓	-	2D Seg	Mid
Woodbury [52]	2019	50	6	Global	Front-view	✓	GPS & IMU & CAN-bus	3D Bbox & 2D Seg	Mid
DriveVista [19]	2019	-	-	EU	Front-view	✓	-	2D Bbox	Mid
DriveVista [19]	2019	67	10	EU	Front-view	✓	GPS & IMU & Infrared Camera	3D Bbox & 2D Seg	Mid
A-100 [95]	2019	650	263.3	NA	Front-view	✓	-	2D Bbox	Mid
TORUS [33]	2019	650	263.3	NA	Front-view	✓	-	Language & 3D Bbox	Mid
LiDARWayne [34]	2019	10714	-	Sim.	360°	✓	-	2D Bbox	Mid
FH [98]	2019	11	6	NA	Front-view	✓	-	2D Bbox	Mid
LiDARWayne [34]	2019	11	6	NA	360°	✓	-	2D Bbox	Mid
TITAN [29]	2019	700	-	AS & NA	Front-view	✓	IMU	2D Bbox	Mid
IEU [96]	2019	901	4.97	NA	Front-view	✓	-	2D Bbox	Mid
AR2 [40]	2020	5.6	5.6	EU	360°	✓	GPS & IMU & CAN-bus	3D Bbox & 2D Seg	Mid
CARMA [94]	2020	26	63.8	NA	Front-view	✓	-	2D Bbox	Mid
DAWN [35]	2019	-	-	Global	Front-view	✓	-	2D Bbox	Mid
Chesapeake [59]	2019	-	-	Global	Front-view	✓	GPS & IMU	2D Bbox	Mid
UNDA [84]	2019	-	-	-	Front-view	✓	GPS & IMU	2D Seg	Mid
ROADNET [93]	2019	-	-	AS	Front-view	✓	-	2D Seg	Mid
Texas-10 [121]	2020	4	-	NA	Front-view	✓	-	2D Seg	Mid
ROADNET [93]	2021	22	-	EU	Front-view	✓	-	2D Bbox & Trajectory	Mid
Reasonable Crowd [34]	2021	-	-	-	Front-view	✓	-	Language	Mid
METRO [11]	2021	1206	30.9	AS	Front-view	✓	GPS	2D Seg	Mid
FordSense [143]	2021	179	-	NA	360°	✓	GPS & IMU	3D Bbox	Mid
MIAD [14]	2022	-	-	Sim.	360°	✓	-	2D Seg, 3D Bbox	Mid
TAN-SIR [32]	2022	-	-	Sim.	Front-view	✓	Infrared Camera	2D Seg	Mid
LIARON [28]	2022	6	-	Sim.	360°	✓	-	2D Bbox	Mid
Wildbook [115]	2022	-	-	AS & NA	Front-view	✓	-	2D Seg	Mid
Chesapeake [59]	2023	1000	5.5	AS & NA	360°	✓	-	3D Obj.	Mid

Dataset	Year	Data Diversity		Sensor	LIDAR	Type	Annotation		
		Scenes	Frames				3D	Inst.	Track
Caltech Lanes [2]	2008	4	1224/1224	-	-	Front-view Image	✓	✓	✓
VPIU [68]	2017	-	20K/20K	✓	✓	Front-view Image	✓	✓	✓
TTuple [128]	2017	6.4K	6.4K/128K	✓	✓	Front-view Image	✓	✓	✓
CULane [96]	2018	-	133K/133K	✓	✓	Front-view Image	✓	✓	✓
ApolloScape [58]	2018	255	115K/115K	✓	✓	Front-view Image	✓	✓	✓
L.L.A.M.A.S [9]	2019	14	79K/100K	✓	✓	Front-view Image	✓	✓	✓
3D Synthetic [50]	2020	-	10K/10K	✓	✓	Front-view Image	✓	✓	✓
CurveLanes [145]	2020	-	150K/150K	✓	✓	Front-view Image	✓	✓	✓
VIL-100 [158]	2021	100	100K/10K	✓	✓	Front-view Image	✓	✓	✓
OpenLane-V1 [20]	2022	1K	200K/200K	✓	✓	Front-view Image	✓	✓	✓
ONCE-3DLane [147]	2022	-	211K/211K	✓	✓	Front-view Image	✓	✓	✓

Subtask	Input	Output	Evaluation	Dataset	Reference
Motion Prediction	Surrounding Traffic Status	Spatiotemporal Trajectory of Single/Multiple Vehicles	Displacement Error	Agnesys [10] Waymo [19] Intersection [54]	[62], [6], [11] [41], [10], [64] [15], [29], [6] [6], [31], [5]
Trajectory Planning	Vehicle, Scenario, Cognitive and Prediction	Trajectory for ego Vehicles	Displacement Error, Safety, Compliance, Comfort	CAHA [34] MetaDrive [9] Apollo [3]	[8], [6], [42] [60], [23], [14] [48], [25], [9] [3], [9], [9], [9]
Path Planning	Maps for Road Network	Routes Connecting to Nodes and Links	Efficiency, Energy Consumption	OpenStreetMap [3] Transportation Networks [43] DTALite [61] FMSF [92]	[4], [7], [8] [43], [13], [10] [8], [44], [23] [152], [64], [17]

Field	Description	Dataset	Reference
Robotics	Enabling People for Multiple Operations and Services	Robotaxi [86], PalJ-X [11], Robotaxi [86]	[96], [85], [90]
V2X	Collaborative Sensing and Decision Making based on Wireless Communication	Data V2X [155], V2X-Sim [74], OPV2V [166]	[105], [118], [94]
UAV	Aerial with Multiple Sensors for Aerial Operation	UAV123 [88], Blackbird [8], UAV1 [9]	[8], [9], [78]
USV	Operation and Control of the Unmanned Surface Vehicle	MOUS [18], MARS123 [82], USVhub [82]	[88], [198], [141]
Allocation and Coordination of Products, Raw Materials, and Services in the Supply Chain NPD Benchmark Datasets [95], LAIRs [96], Devy data [52] [86], [96], [149]			

AD Challenge - 2024

contact@opendriveLab.com

Timeline

2023.12

Challenge Release

2024.01

Dataset / Evaluation Release

2024.03

Challenge Begin

2024.06

Winners Announcenment

Tentative Tracks

[T1] DriveLM: Driving through Language

[T2] CARLA: Closed-loop Driving

[T3] OpenLane-V2: Scene Reasoning

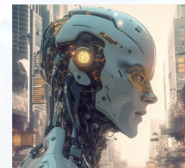
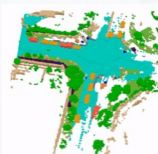
[T4] Foundation Model Challenge

[T5] nuScenes: Occupancy

[T6] nuPlan: Planning

[T7] DriveScene Generation

[T8] Prompt Design on XGPT



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Thanks

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