NEURAL INFORMATION PROCESSING SYSTEMS

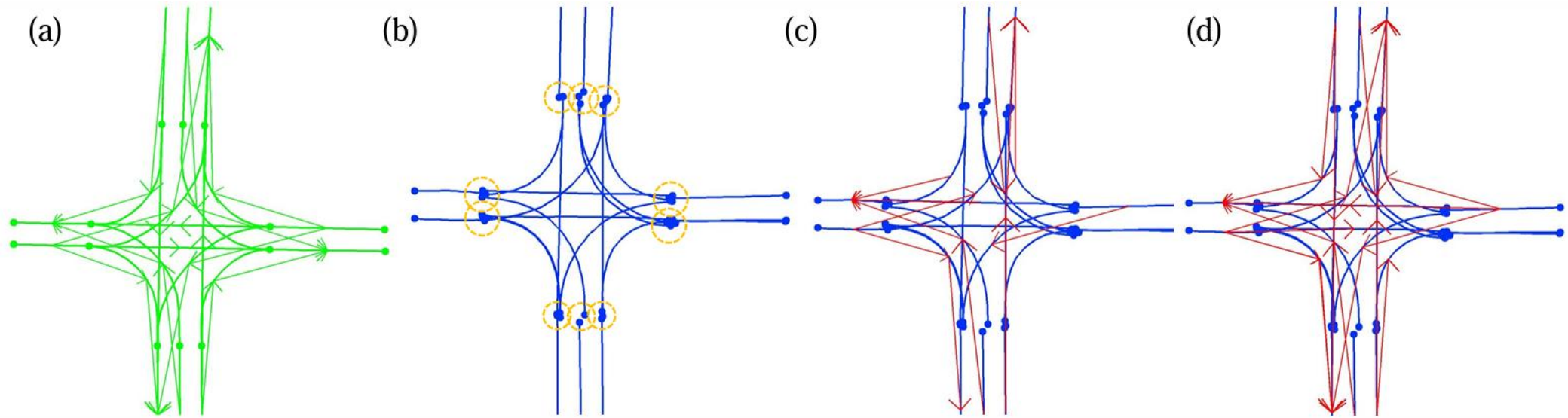
TopoLogic: An Interpretable Pipeline for Lane Topology Reasoning on Driving Scenes

Yanping Fu, Wenbin Liao, Xinyuan Liu, Hang Xu, Yike Ma, Yucheng Zhang, Feng Dai

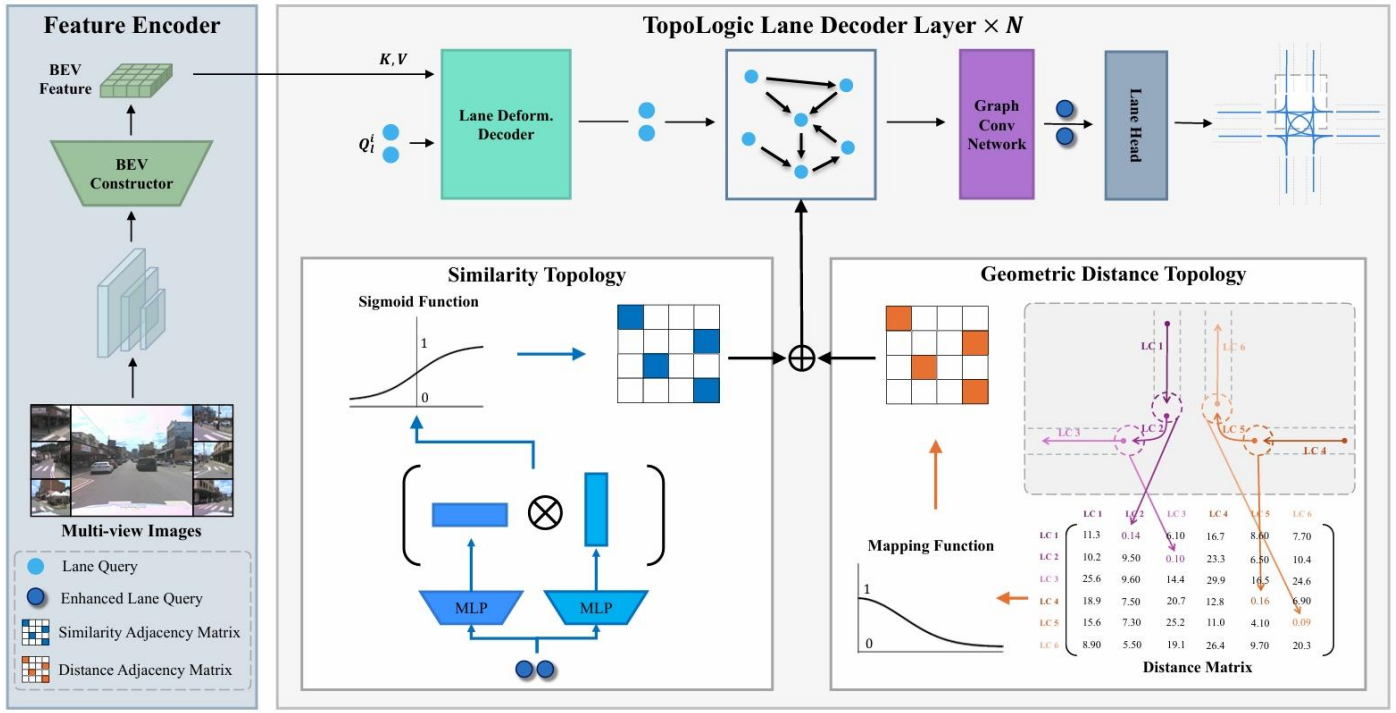
Motivation

1. Slightly shifted endpoints: Lanes may be erroneously classified by MLP as disconnected, as Figure (c).

2. Geometric distance method: Lane topology reasoning is significantly improved, as Figure (d).



Pipeline



1. An image encoder for feature extraction and transformation, and a lane decoder responsible for end-to-end topology reasoning.

2. Decoder utilizes the proposed lane geometric distance topology and lane similarity topology

3. Fuse two topology into the final lane topology, which is facilitated through GNN to augment lane learning in the next decoder layer.

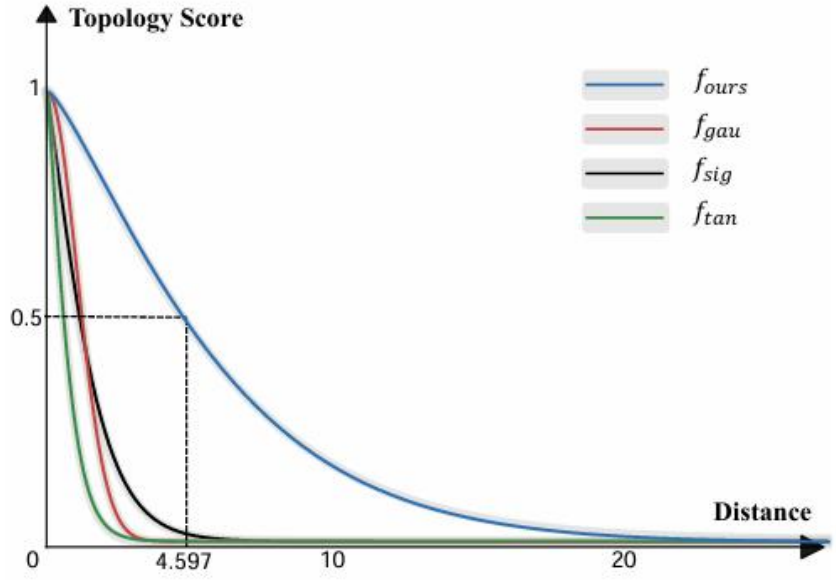
Lane Geometric Distance Topology

Lane Geometric Distance Matrix.

$$l_0, \ldots, l_{n-1} = \text{LaneHead}(Q_l^i)$$

$$d_{ij} = \mid l_i^{end} - l_j^{start} \mid$$

$$D = \{d_{ij} \mid i, j = 0 \ldots n-1\}$$



Distance to Topology Mapping Function.

$$f_{ours} = e^{-\frac{x^{\alpha}}{\lambda \cdot \sigma}}$$

$$f_{gau} = e^{-\frac{x^2}{2}} \quad (a), \quad f_{sig} = \frac{2}{1+e^x} \quad (b), \quad f_{tan} = \frac{e^{-x} - e^x}{e^{-x} + e^x} + 1 \quad (c)$$

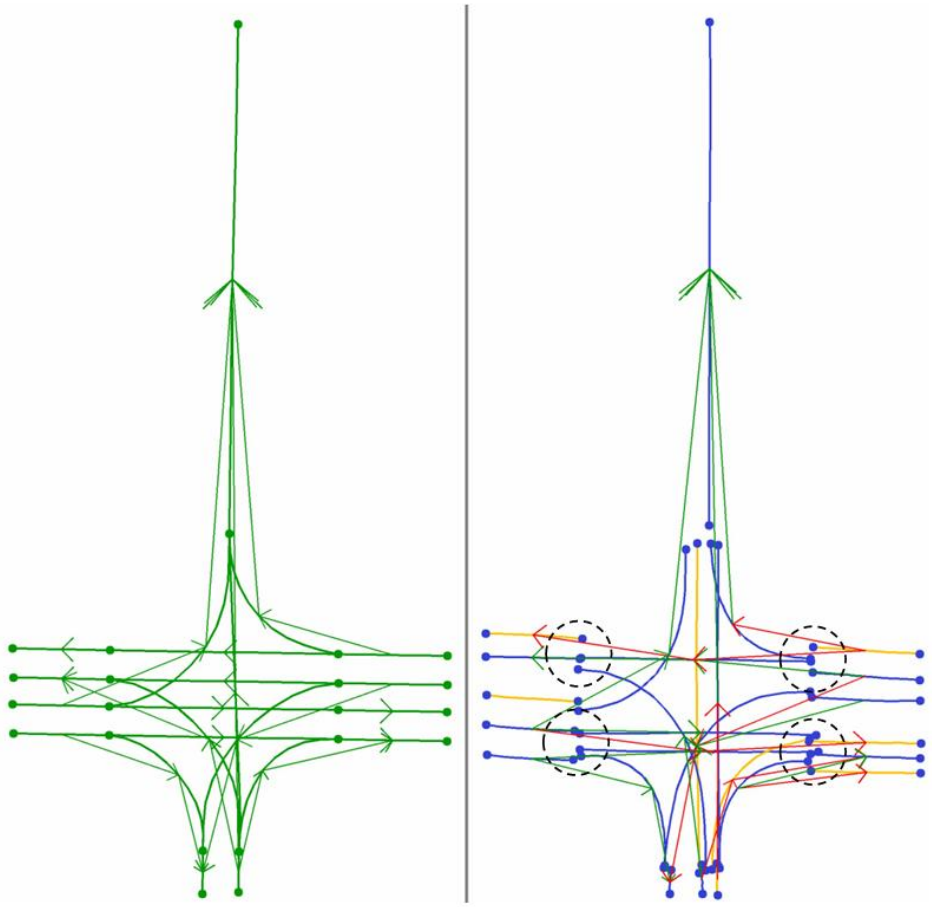
Lane Similarity Topology

Lane topology reasoning based on the geometric distance of lane lines can achieve commendable results when the detection of lane lines is accurate, as Figure.

$$Q_{emb_1}, Q_{emb_2} = \mathrm{MLP}_1(Q_l^i), \mathrm{MLP}_2(Q_l^i)$$
$$S = \mathrm{matmul}(Q_{emb_1}, \mathrm{transpose}(Q_{emb_2}))$$
$$G_{sim} = \mathrm{sigmoid}(S)$$

Lane-Lane Topology

$$G = \lambda_1 \cdot G_{dis} + \lambda_2 \cdot G_{sim}$$



Experiment

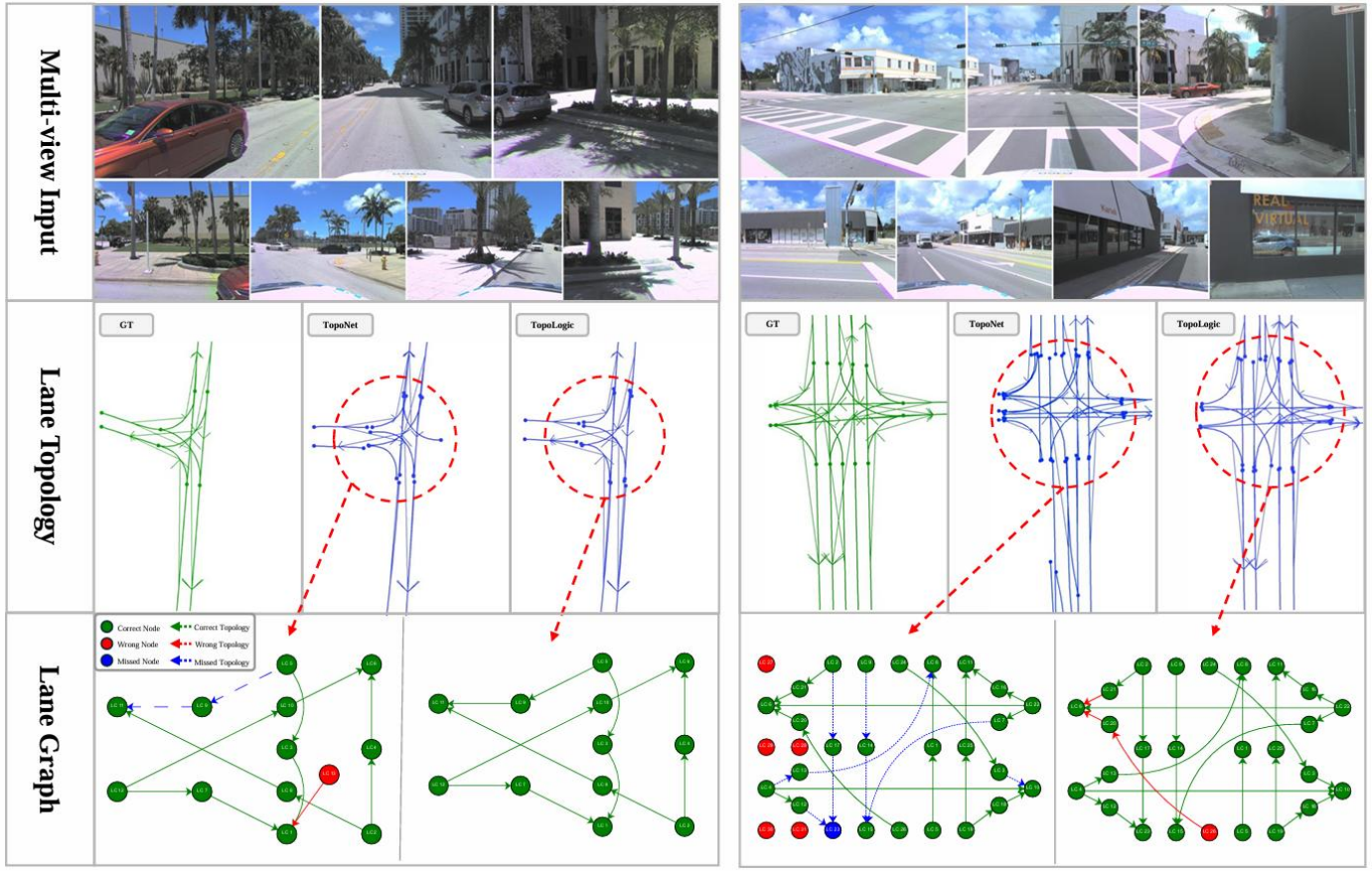
Performance comparison with state-of-the-art methods on OpenLane-V2 benchmark on centerline. **Since the ultimate goal of perception is reasoning, we believe that topology metrics are what should be paid more attention.**

Data	Method	SDMap	DET_l ↑	DET_t ↑	v1.0.0			v2.1.0		
					TOP_{ll} ↑	TOP_{lt} ↑	OLS↑	TOP_{ll} ↑	TOP_{lt} ↑	OLS↑
subset_A	STSU [16]	×	12.7	43.0	0.5	15.1	25.4	2.9	19.8	29.3
	VectorMapNet [6]	×	11.1	41.7	0.4	5.9	20.8	2.7	9.2	24.9
	MapTR [41]	×	17.7	43.5	1.1	10.4	26.0	5.9	15.1	31.0
	TopoNet [1]	×	28.6	48.6	4.1	20.8	35.6	10.9	23.8	39.8
	TopoMLP [9]	×	28.3	**50.0**	7.2	22.8	38.2	19.0	23.4	42.2
	TopoLogic	×	**29.9**	47.2	**18.6**	**21.5**	**41.6**	**23.9**	**25.4**	**44.1**
	SMERF [13]	✓	33.4	**48.6**	7.5	23.4	39.4	15.4	25.4	42.9
	TopoLogic	✓	**34.4**	48.3	**23.4**	**24.4**	**45.1**	**28.9**	**28.7**	**47.5**
subset_B	STSU [16]	×	8.2	43.9	0.0	9.4	21.2	-	-	-
	VectorMapNet [6]	×	3.5	49.1	0.0	1.4	16.3	-	-	-
	MapTR [41]	×	15.2	54.0	0.5	6.1	25.2	-	-	-
	TopoNet [1]	×	24.3	55.0	2.5	14.2	33.2	6.7	16.7	36.8
	TopoMLP [9]	×	**26.6**	**58.3**	7.6	**17.8**	38.7	-	-	-
	TopoLogic	×	25.9	54.7	**15.1**	15.1	**39.6**	**21.6**	**17.9**	**42.3**

Qualitative Analysis

NEURAL INFORMATION PROCESSING SYSTEMS

A qualitative comparison between TopoLogic and TopoNet. Specifically, two traffic scenes are selected for analysis, and the results of lane line detection and topology reasoning are visualized.



NEURAL INFORMATION PROCESSING SYSTEMS

Thank You!

Yanping Fu, Wenbin Liao, Xinyuan Liu, Hang Xu, Yike Ma, Yucheng Zhang, Feng Dai