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RS2G: Data-Driven Scene-Graph Extraction and Embedding for Robust Autonomous Perception and Scenario Understanding

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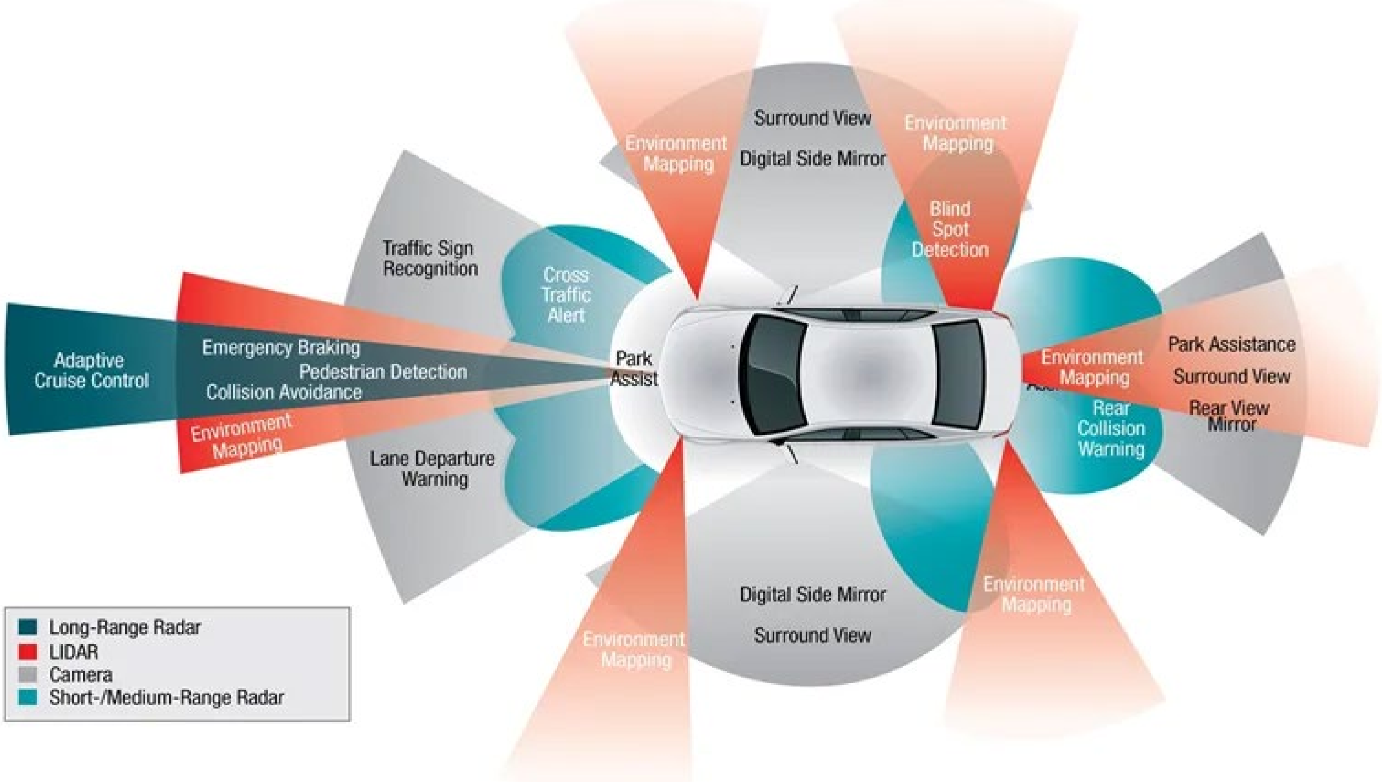
An Overview of Autonomous Driving



RS2G focuses on **subject risk assessment.**

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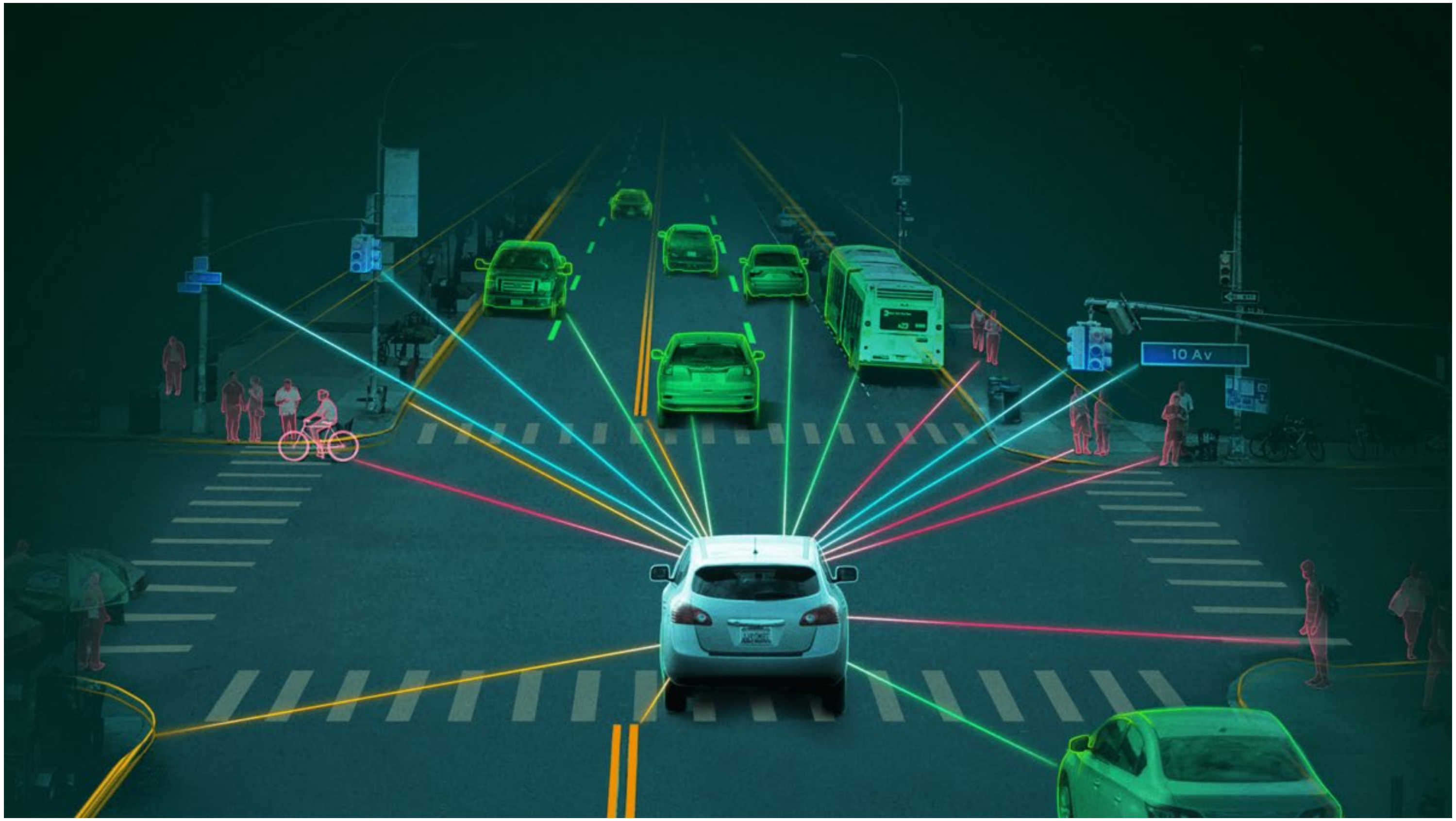
Keyword: Relations



Effectively modeling the **relations** among road users is very important for autonomous vehicle to understand the surrounding environment.

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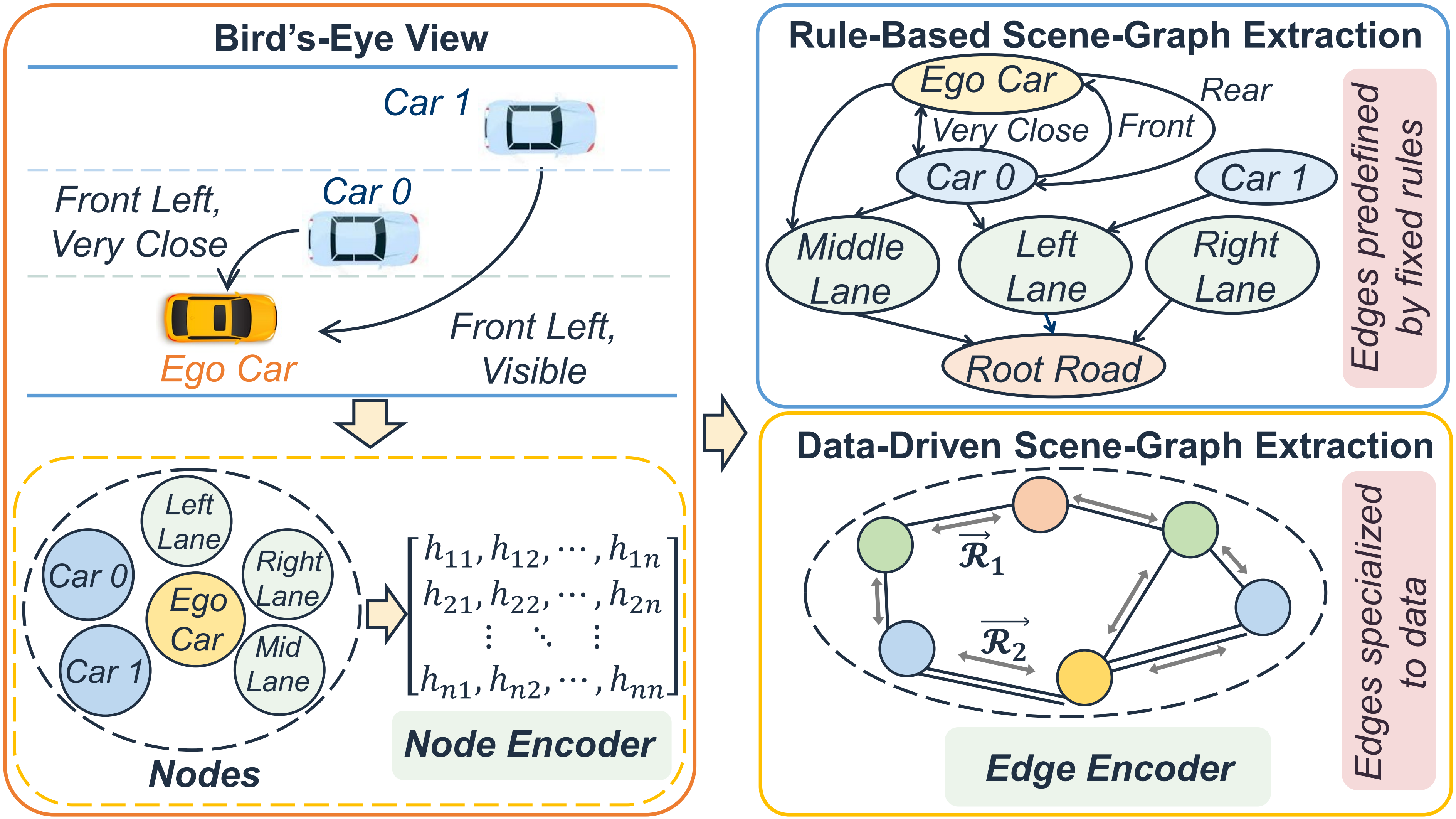
Data-Driven Scene-Graph vs. Rule-Based Scene-Graph



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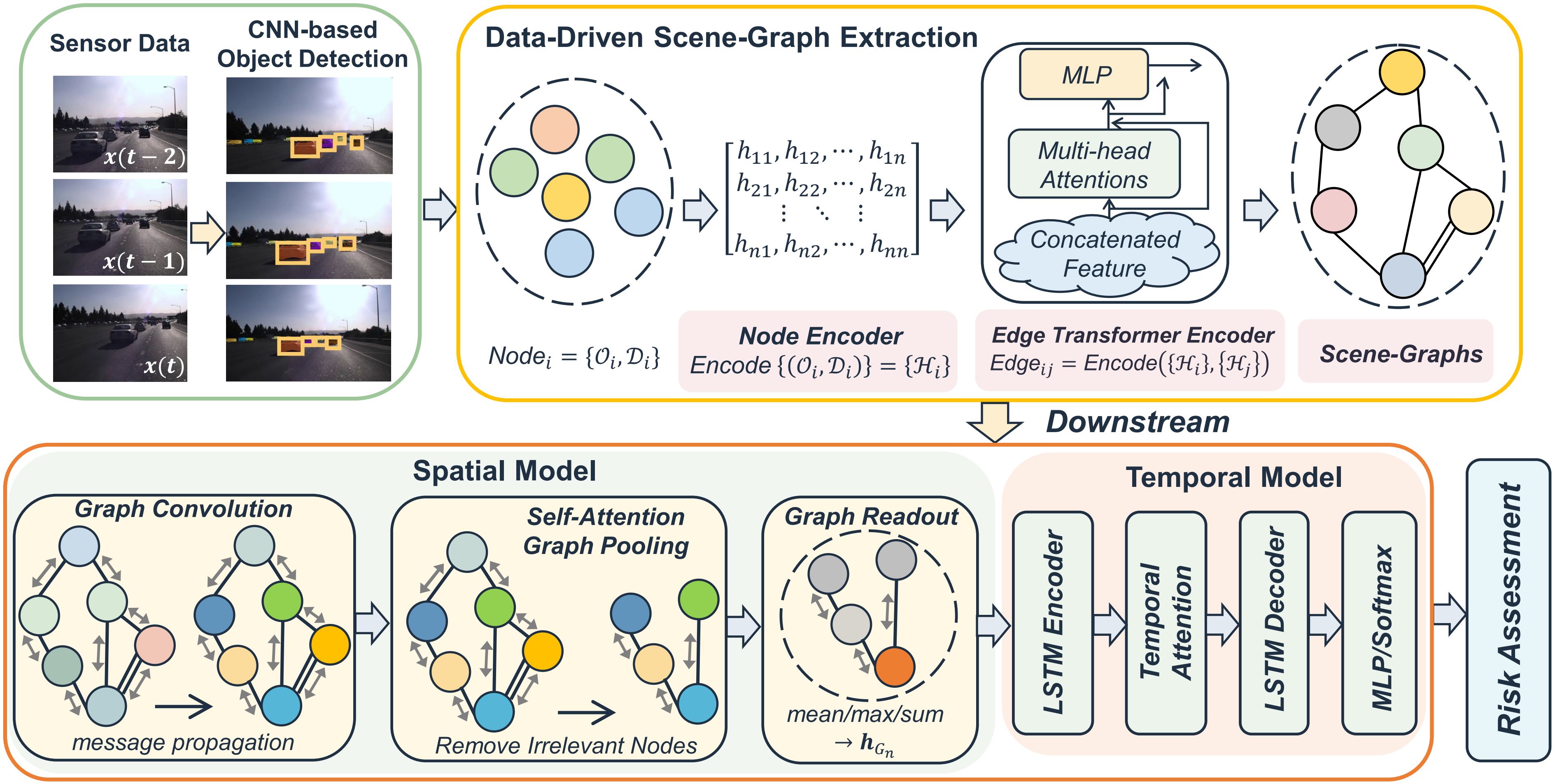
RS2G Workflow



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Data-Driven Scene-Graph Extraction

Algorithm 1: Data-Driven Scene-Graph Extraction

Input: Objects $\mathcal{O}_t$ and their attributes $\mathcal{D}_t$ at time t.

Output: Scene-graph $\mathcal{G}_t$ at time t.

def Ψ $(\mathcal{O}_t, \mathcal{D}_t)$ **:**

- $\mathcal{H}_t \leftarrow \emptyset$, $\mathcal{A}_t \leftarrow \mathbf{0}_{n \times n}$ ▷ initialize outputs
- **for** $o_j, \mathbf{d}_j \in \mathcal{O}_t, \mathcal{D}_t$ **do**
  - $\mathbf{h}_j \leftarrow Encode_{node}(o_j, \mathbf{d}_j)$ ▷ node encoding
  - $\mathcal{H}_t.append(\mathbf{h}_j)$
- $\mathcal{C} \leftarrow \mathcal{H}_t \times \mathcal{H}_t$ ▷ get all pair of nodes
- **for** *relation* $r \in \mathcal{R}$ **do**
  - **for** *edge* $(\mathbf{h}_j, \mathbf{h}_k) \in \mathcal{C}$ **do**
    - $(\mathcal{A}_t)_{r,j,k} \leftarrow MLP(Encode_{edge}(r, \mathbf{h}_j, \mathbf{h}_k))$
- $\mathcal{G}_t \leftarrow \{\mathcal{H}_t, \mathcal{A}_t\}$
- **return** $\mathcal{G}_t$

Experimental Result

- Subjective Risk Assessment
- Transfer Learning

Dataset	Graph Extraction	Accuracy	MCC	AUC
271-carla	None	73.17%	0.1887	0.8043
	Rule-Based	82.93%	0.5173	0.8098
	RS2G (1D MLP)	84.51%	0.2093	0.9338
	RS2G (2D MLP)	**86.59%**	**0.468**	**0.9578**
	RS2G (Transformer)	84.15%	0.402	0.9362
1043-carla	None	71.66%	0.1111	0.7173
	Rule-Based	91.43%	0.7217	0.971
	RS2G (1D MLP)	91.72%	0.6840	0.9643
	RS2G (2D MLP)	93.31%	0.7426	0.7949
	RS2G (Transformer)	**97.13%**	**0.8823**	**0.9686**
1361-honda	None	60.39%	0.0391	0.7110
	Rule-Based	86.31%	0.2445	0.9341
	RS2G (1D MLP)	87.04%	0.1626	0.9315
	RS2G (2D MLP)	89.00%	0.3029	0.9383
	RS2G (Transformer)	**89.98%**	**0.404**	**0.9495**
620-dash	None	48.92%	-0.1749	0.5256
	Rule-Based	67.20%	0.3428	0.6966
	RS2G (1D MLP)	68.82%	0.3967	0.7403
	RS2G (2D MLP)	**72.04%**	**0.4398**	**0.8047**
	RS2G (Transformer)	68.28%	0.3635	0.7354

Comparing experimental result for subjective risk assessment.

Dataset	Graph Extraction	Accuracy	MCC	AUC
271-carla to 620-dash	None	52.58%	0.0333	0.5126
	Rule-Based	48.22%	0.0238	0.4975
	RS2G(2D MLP)	57.25%	0.1398	0.5669
	RS2G(Transformer)	**64.68%**	**0.2957**	**0.6831**
1043-carla to 620-dash	None	49.03%	-0.0432	0.4999
	Rule-Based	50.96%	0.0021	0.5093
	RS2G(2D MLP)	60.65%	0.2089	0.6265
	RS2G (Transformer)	**66.29%**	**0.3293**	**0.6964**

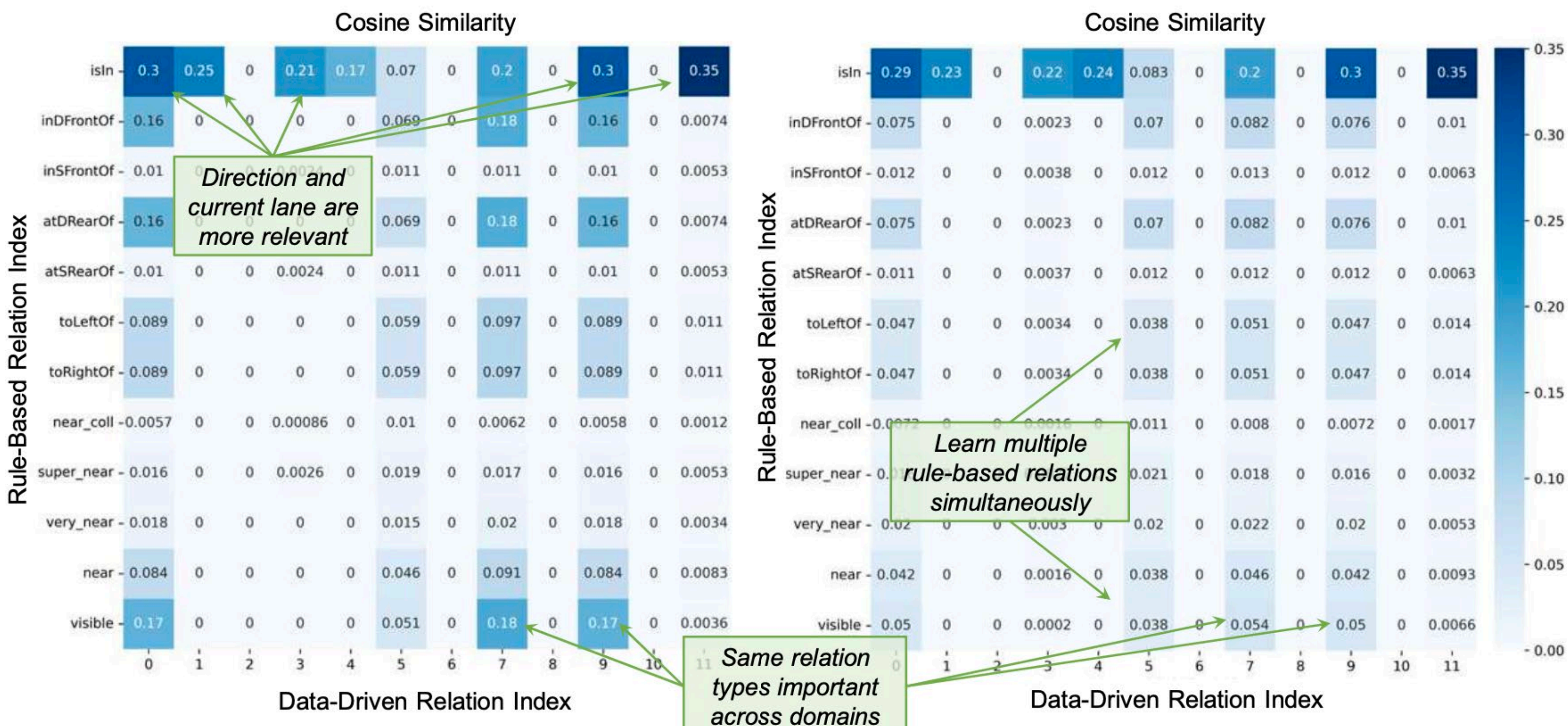
Transfer Learning comparison between (i) the SOTA deep learning model, (ii) the SOTA graph learning model with rule-based graph extraction, and (iii) RS2G(2D MLP) and RS2G(Transformer)

Ablation Study I: Downstream Component Analysis

Graph Extraction	Spatial Model	Temporal Model	Accuracy	MCC	AUC
Rule-Based	MLP	mean	52.15%	0.0000	0.4973
Rule-Based	MLP	LSTM	62.90%	0.2741	0.6811
Rule-Based	MRGCN	mean	63.44%	0.2696	0.6867
Rule-Based	MRGCN	LSTM	**75.27%**	**0.5197**	**0.8248**
RS2G	MLP	mean	81.74%	0.1857	0.9228
RS2G	MLP	LSTM	81.45%	0.402	0.9472
RS2G	MRGCN	mean	**87.80%**	**0.5403**	**0.9468**
RS2G	MRGCN	LSTM	84.15%	0.402	0.9362

Impact of each component of the downstream model. Models are trained and evaluated on the 271-dash dataset. We demonstrate the impact of different spatial and temporal modules using rule-based graph extraction and RS2G (Transformer).

Ablation Study II: Cosine Relation Similarity



(a) ***1043-Carla***   (b) ***620-dash***

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Thank You!

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Open-sourced code at https://github.com/AICPS/RS2G.git