



KnowVal: A Knowledge-Augmented and Value-Guided Autonomous Driving System

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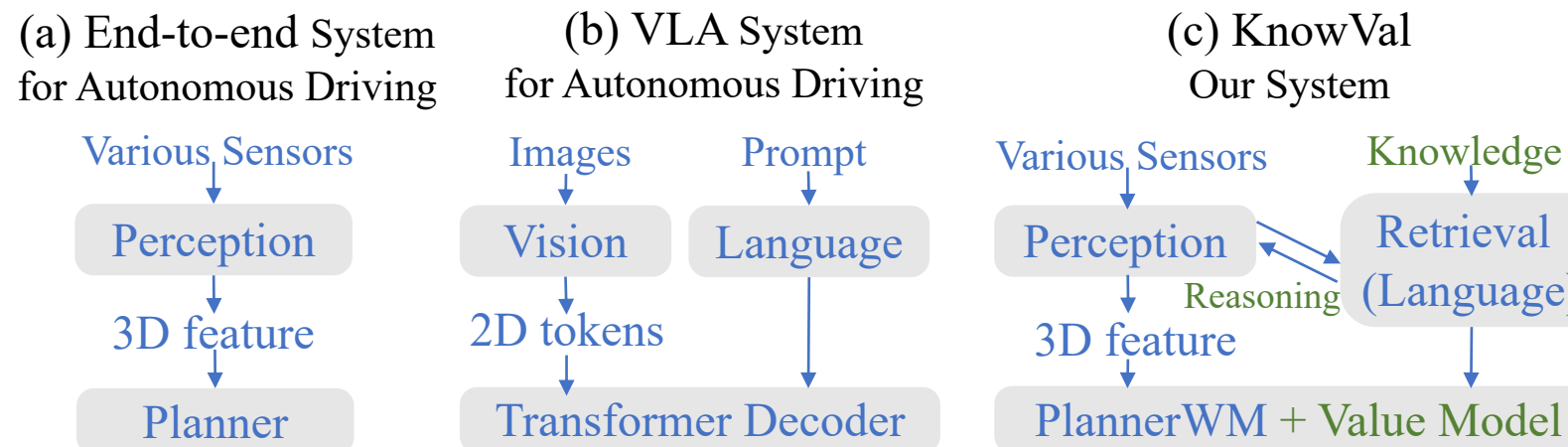
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Introduction

Motivation

Visual-language reasoning, driving knowledge, and value alignment are essential for advanced autonomous driving systems. However, existing approaches largely rely on data-driven learning, making it difficult to capture the complex logic underlying decision-making through imitation or limited reinforcement rewards.

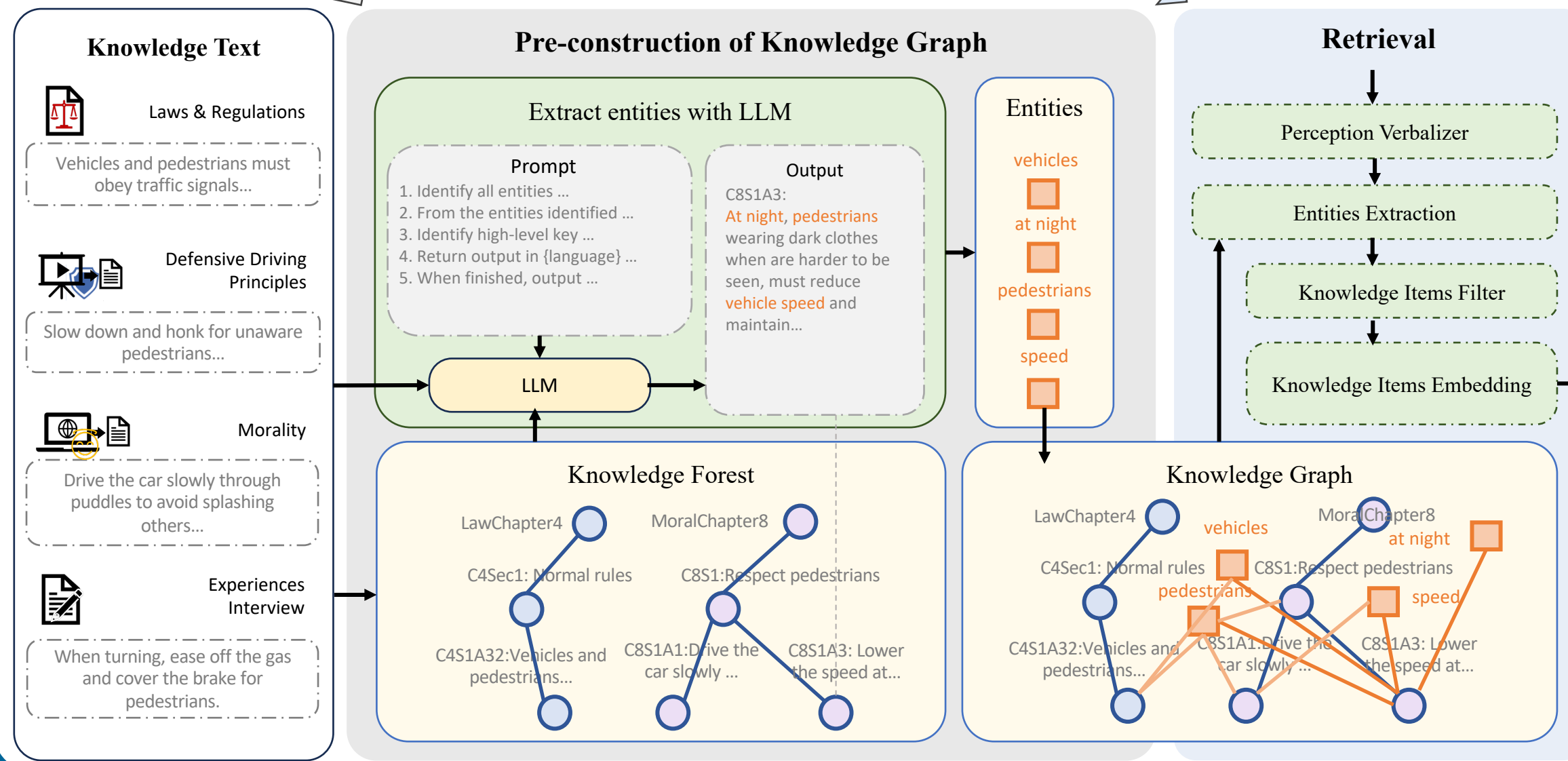
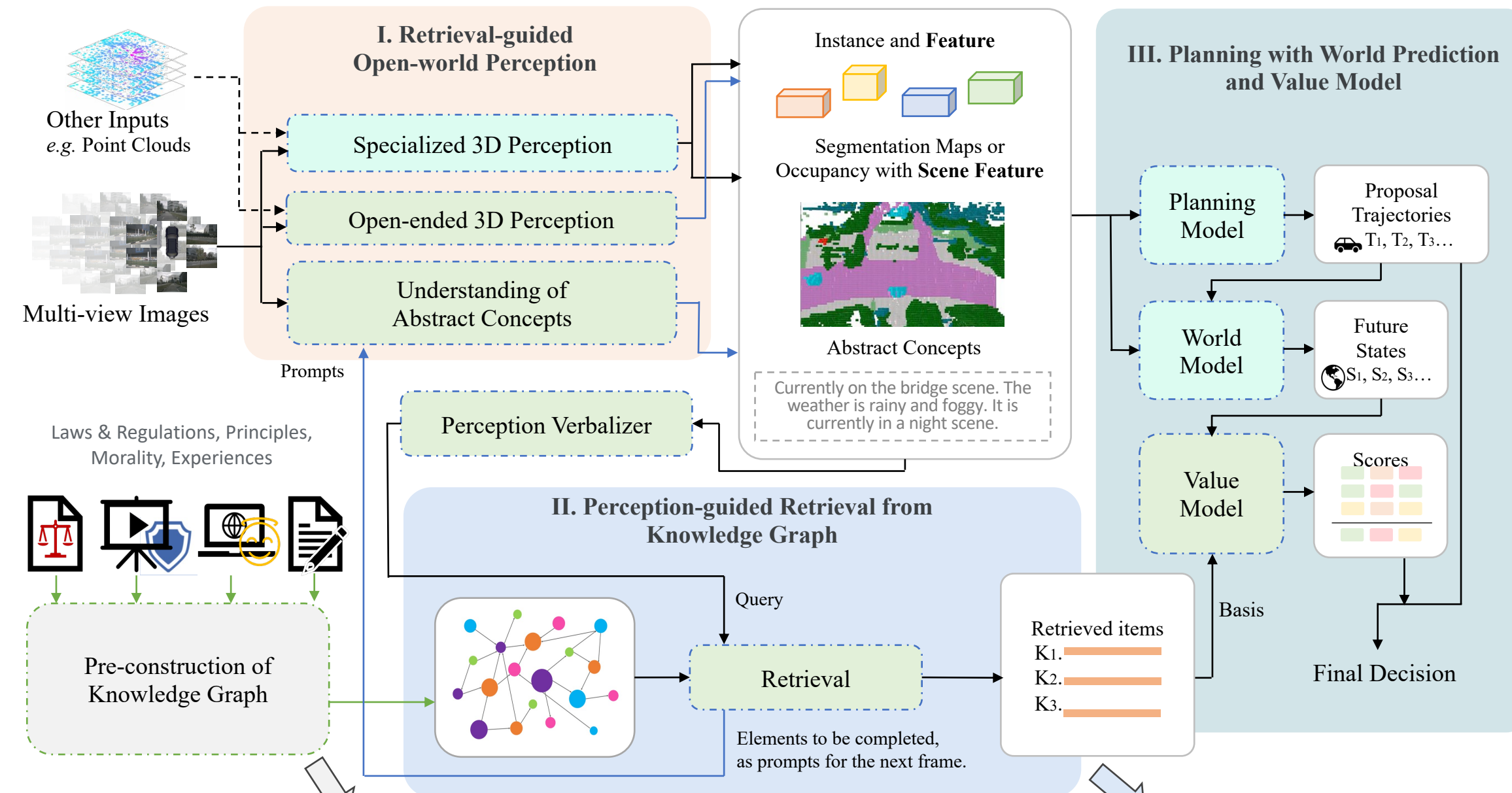


	a) End-to-end	b) VLA	c) KnowVal
Knowledge	×	×	✓ Knowledge Retrieval
3D Feature	✓	×	✓
Reasoning	×	✓ Language Reasoning	✓ Vision-Language Reasoning
Values	✓ If-else or Rewards	✓ If-else or Rewards	✓ Value Model

Contribution

- We propose a new autonomous driving system, **KnowVal**, that enables **visual-language reasoning** through the synergistic interaction between perception and knowledge retrieval.
- We construct a comprehensive **driving knowledge graph** encompassing traffic laws, principles, and moral considerations.
- We develop an efficient **LLM-based retrieval** mechanism for it.
- We design a planner that integrates a **world model for future-state prediction** and a **Value Model for outcome evaluation**.
- We construct a human-preference dataset is also curated to train the Value Model.
- KnowVal achieves the lowest collision rate on nuScenes and state-of-the-art performance on Bench2Drive and NVISIM.

Method: KnowVal



Experiments

Planning results on nuScenes

Method	Input	UniAD Metrics				VAD/STP3 Metrics												
		L2 (m) ↓		Collision Rate (%) ↓		L2 (m) ↓		Collision Rate (%) ↓										
ST-P3 [9]	C	1.72	3.26	4.86	3.28	0.44	1.08	3.01	1.51	1.33	2.11	2.90	2.11	0.23	0.62	1.27	0.71	
OcNet [28]	C	1.29	2.13	2.99	2.14	0.21	0.59	1.37	0.72	-	-	-	-	-	-	-	-	-
UniAD [10]	C	0.48	0.96	1.65	1.03	0.05	0.17	0.71	0.31	0.45	0.70	1.04	0.73	0.62	0.58	0.63	0.61	
VAD-Base [15]	C	0.54	1.15	1.98	1.22	0.04	0.39	1.17	0.53	0.41	0.70	1.05	0.72	0.07	0.17	0.41	0.22	
PARA-Drive [29]	C	-	-	-	-	-	-	-	-	0.25	0.46	0.74	0.48	0.14	0.23	0.39	0.25	
SparseDrive [27]	C	0.44	0.92	1.69	1.01	0.07	0.19	0.71	0.32	0.29	0.58	0.96	0.61	0.01	0.05	0.18	0.08	
MomAD [26]	C	0.43	0.88	1.62	0.98	0.06	0.16	0.68	0.30	0.31	0.57	0.91	0.60	0.01	0.05	0.22	0.09	
SSR [17]	C	0.24	0.65	1.36	0.75	0.00	0.10	0.36	0.15	0.18	0.36	0.63	0.39	0.01	0.04	0.12	0.06	
BridgeAD-B [35]	C	-	-	-	-	-	-	-	-	0.28	0.55	0.92	0.58	0.00	0.04	0.20	0.08	
DiffusionDrive [20]	C	-	-	-	-	-	-	-	-	0.27	0.54	0.90	0.57	0.03	0.05	0.16	0.08	
GenAD [36]	C	0.36	0.83	1.56	0.91	0.06	0.23	1.00	0.43	0.28	0.49	0.78	0.52	0.08	0.14	0.34	0.19	
KnowVal-GenAD	C	0.46	1.35	2.72	1.51	0.00	0.20	0.80	0.33	0.10	0.20	0.65	0.01	0.08	0.25	0.11	0.08	
HENet++ [32]	RC	0.39	1.11	2.36	1.29	0.00	0.06	0.33	0.13	0.24	0.50	0.91	0.55	0.01	0.03	0.10	0.05	
KnowVal-HENet++	RC	0.42	1.19	2.35	1.32	0.00	0.10	0.25	0.12	0.26	0.54	0.94	0.58	0.00	0.01	0.08	0.03	

Closed-loop results on Bench2Drive

Method	Expert	Paradigm	DS↑	SR↑
AD-MLP [34]	Think2Drive	E2E	18.05	00.00
TCP [30]	Think2Drive	E2E	40.70	15.00
TCP-traj [30]	Think2Drive	E2E	59.90	30.00
UniAD-Base [10]	Think2Drive	E2E	45.81	16.36
VAD [15]	Think2Drive	E2E	42.35	15.00
ThinkTwice [12]	Think2Drive	E2E	62.44	31.23
DriveAdapter [11]	Think2Drive	E2E	64.22	33.08
DriveTrans. [14]	Think2Drive	E2E	63.46	35.01
ORION [6]	Think2Drive	VLA	77.74	54.62
DiffusionDrive [20]	PDM-Lite	E2E	77.68	52.72
SimLingo [23]	PDM-Lite	VLA	85.07	67.27
KnowVal-SimLingo	PDM-Lite	KnowVal	88.42	69.03

Results on NAVSIM

Method	Expert	Mod.	NC↑	DAC↑	TTC↑	Conf.↑	EP↑	PDMS↑
VADv2 [2]	LC	97.2	89.1	91.6	100	76.0	80.9	
Hydra-MDP [19]	LC	98.3	96.0	94.6	100	78.7	86.5	
DiffusionDrive [20]	LC	98.2	96.2	94.7	100	82.2	88.1	
KnowVal-DiffusionDrive	LC	99.0	98.3	96.3	100	84.3	90.9	
UniAD [10]	C	97.8	91.9	92.9	100	78.8	83.4	
PARA-Drive [29]	C	97.9	92.4	93.0	99.8	79.3	84.0	
iPad [7]	C	98.6	98.3	94.9	100	88.0	91.7	
KnowVal-iPad	C	99.2	98.7	95.4	100	88.1	92.9	

Closed-loop results on HiDrive (https://github.com/VDIGPKU/HiDrive)

Method	Overall				Basic Set				Hard Set				Thorny Set			
	DS	RC	LS	ES	DS	RC	LS	ES	DS	RC	LS	ES	DS	RC	LS	ES
TCP [24]	18.4	23.7	27.8	89.3	18.5	24.1	27.2	91.0	17.6	21.4	28.0	87.1	19.1	25.5	30.1	85.0
UniAD-Base [9]	21.9	26.6	32.1	91.6	21.2	26.7	31.6	93.7	23.6	25.3	30.8	89.8	22.3	28.0	36.4	85.2
VAD [14]	20.1	24.3	30.7	89.3	19.2	24.2	30.0	91.2	22.4	24.6	31.1	87.3	20.0	24.6	33.0	84.2
ThinkTwice [11]	28.3	35.6	38.9	92.4	26.3	36.8	38.3	95.2	33.5	31.8	39.3	88.7	29.0	36.0	41.3	86.0
DriveAdapter [10]	29.5	40.0	40.3	92.4	27.6	41.8	40.0	95.3	34.0	34.7	39.0	89.0	30.8	40.3	43.7	84.5
DriveTrans. [13]	31.0	40.3	43.1	91.9	28.9	40.2	42.7	94.5	36.6	36.2	43.1	88.5	31.3	47.0	45.0	85.8
ORION [6]	37.4	65.3	54.8	93.5	34.4	62.9	51.4	95.5	43.8	70.1	61.3	91.4	40.5	68.7	59.5	87.8
Diffu.Drive [16]	34.2	58.3	49.1	91.4	30.8	56.0	45.3	93.4	41.3	64.0	56.4	89.4	38.1	59.6	54.8	85.3
SimLingo [18]	42.3	70.5	63.3	94.8	39.1	66.7	60.9	96.3	50.4	77.4	70.7	92.1	43.8	76.2	62.1	92.7
KnowVal [25]	46.6	73.8	69.3	97.4	42.6	70.5	66.0	98.3	56.8	79.9	78.5	96.3	47.9	79.0	69.4	95.3

Illustration of the inference process of KnowVal

