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Continuously Learning, Adapting, and Improving: A Dual-Process Approach to Autonomous Driving

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Introduction

What is this paper about?

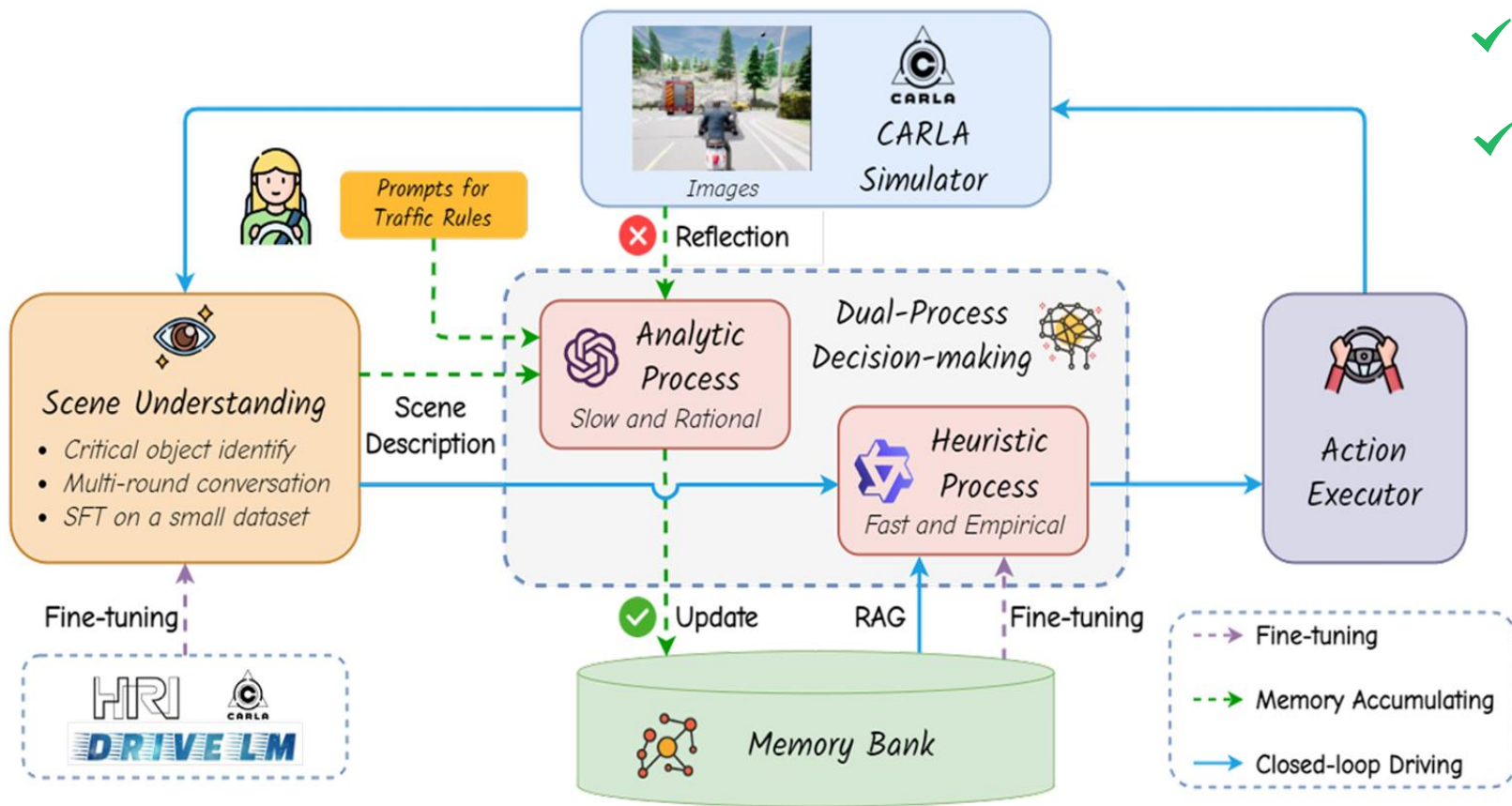
- ❑ A closed-loop AD system capable of reasoning about unseen scenarios and utilizing knowledge in a human cognition manner.
- ❑ A closed-loop learning process involving continuous interaction and exploration, along with rational analysis.

What dose this paper features?

- ✓ We proposed LeapAD that emulates the *critical object attention mechanisms* and the *learning processes observed in human driving behavior*.
- ✓ Dual-process decision-making module inspired by human cognition theory, enabling *fast and empirical Heuristic Process* to inherit the capabilities of *slow and rational Analytic Process* in a self-supervised manner.
- ✓ Memory bank and reflection mechanism, enabling the system to achieve *continuous learning and generalization capabilities* in a closed-loop setup.

Method

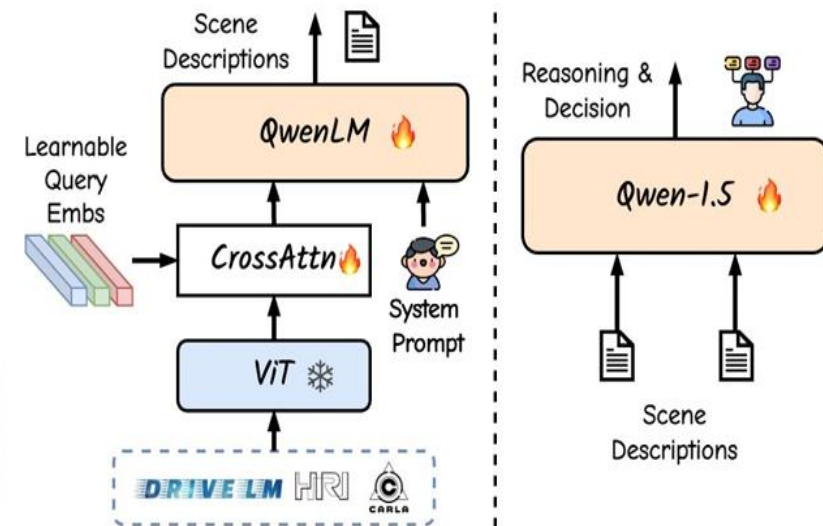
Overall pipeline of the proposed LeapAD



✓ Scene Understanding: Qwen-VL-7B

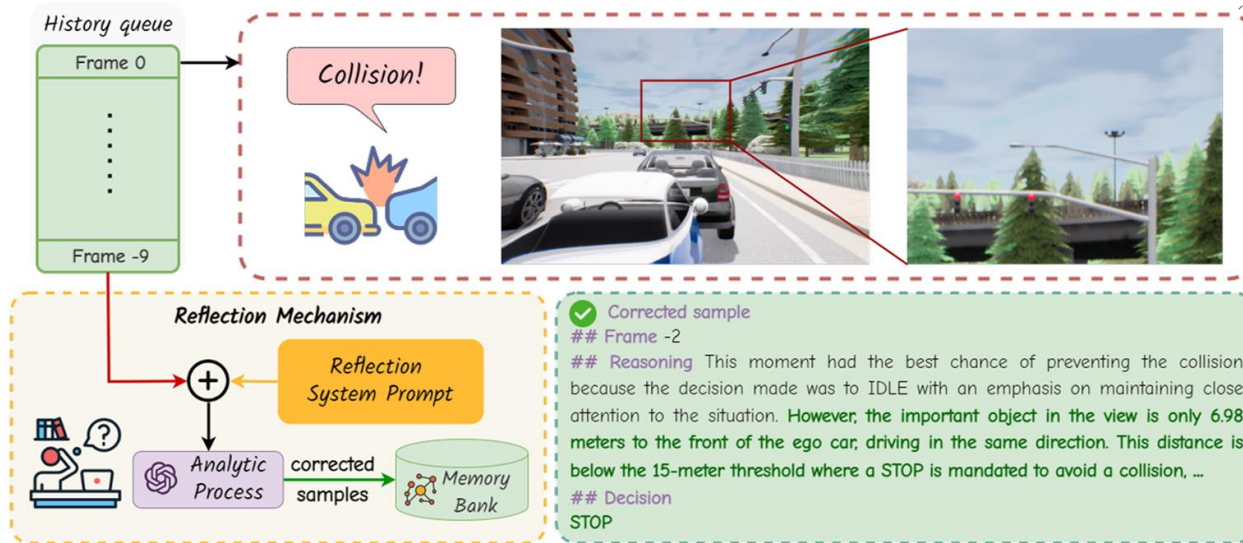
✓ Analytic Process: GPT-4

✓ Heuristic Process: Qwen-1.5-1.8B

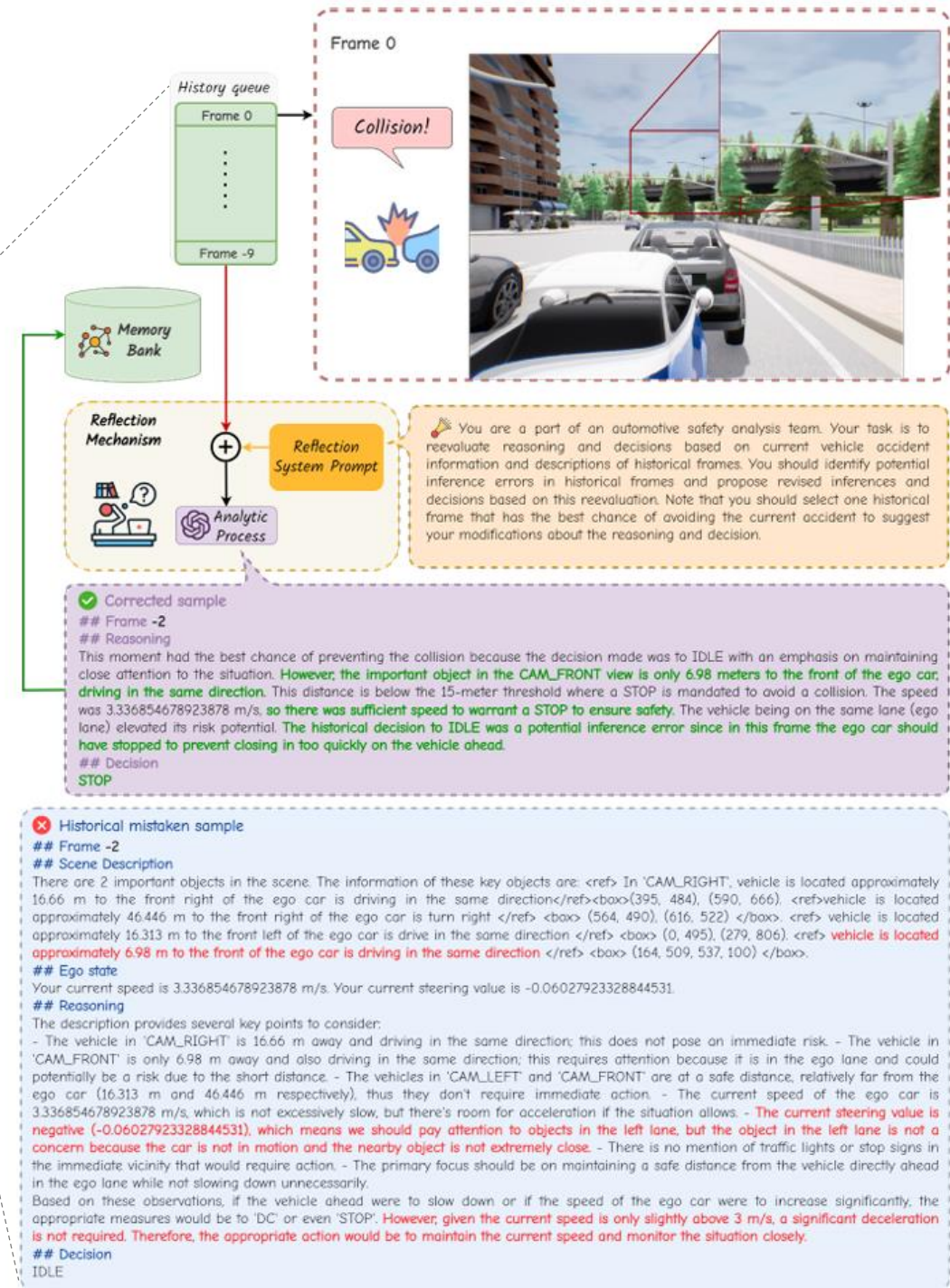


Method

Reflection mechanism



- When Heuristic Process encounters traffic accidents, the Analytic Process intervenes.
- Analyze historical frames to pinpoint errors and provide corrected samples.
- The corrected samples are then integrated into the memory bank to facilitate continuous learning.



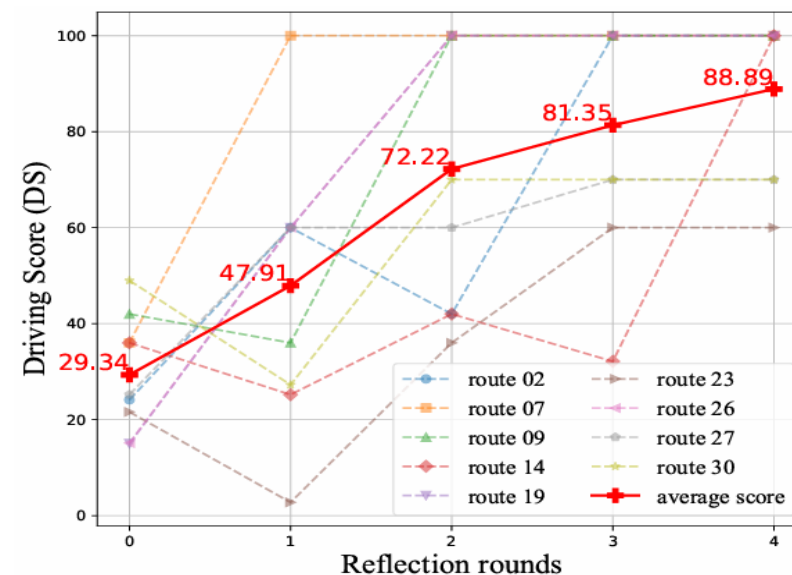
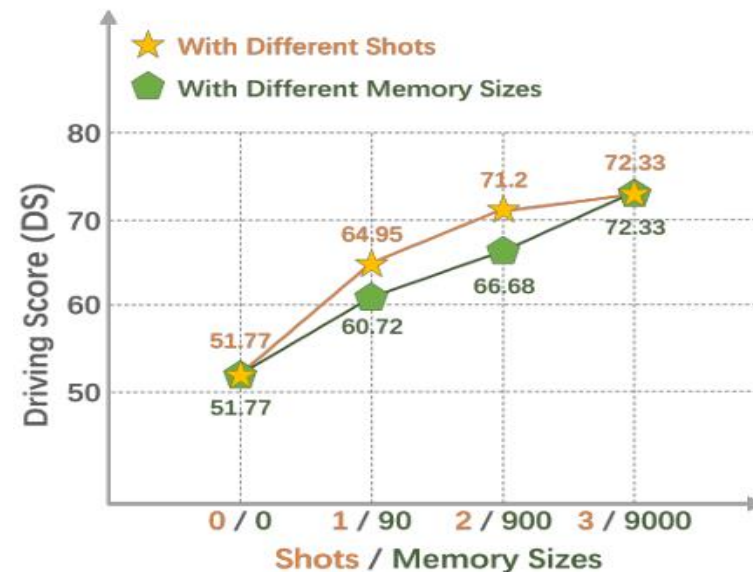
Experiments

- LeapAD demonstrated superior performance with a smaller data footprint on CARLA Short benchmark.

Method	Modality	Type	Annotations	DS \uparrow	RC \uparrow
InterFuser	L+C	DD	3M	94.95\pm1.91	95.19\pm2.57
TransFuser	L+C	DD	228K	54.52 \pm 4.29	78.41 \pm 3.75
VAD	C	DD	228K	64.30	87.30
NEAT	C	DD	130K	58.70 \pm 4.11	77.32 \pm 4.91
Roach	C	DD	-	65.26 \pm 3.63	88.24 \pm 5.16
WOR	C	DD	1M	64.79 \pm 5.53	87.47 \pm 4.68
LBC	C	DD	157K	30.97 \pm 4.17	55.01 \pm 5.14
CILRS	C	DD	720K	7.47 \pm 2.51	13.40 \pm 1.09
VLM + GPT-4	C	KD	11K	81.31 \pm 2.37	94.22 \pm 3.18
LeapAD (w/o Town05)	C	KD	11K	75.73 \pm 1.36	92.10 \pm 1.44
LeapAD	C	KD	11K	83.11\pm0.28	94.98\pm0.54

- Generalization and transferability of the experience in the memory bank.

Test town	$L_{avg}(m)$	Memory (Town01-04, 06)		Memory (Town05)		DS \uparrow	RC \uparrow	IS \uparrow
		Few-shot	SFT	Few-shot	SFT			
Town05	70.1		✓			66.40	90.40	73.81
		✓	✓			75.73	92.10	82.66
					✓	69.90	91.79	76.64
				✓	✓	78.07	91.69	85.89
		✓	✓	✓	✓	83.11	94.98	87.78
Town01	129.1			✓	✓	68.68	100.0	68.68
Town04	119.3			✓	✓	95.08	97.96	96.56



Case Study

✓ In different dynamic environment.



✓ Corner case where a bicycle suddenly appears.



Scene Description

There are 2 important objects in the scene. The information of these key objects are: `<ref> In 'CAM_FRONT', vehicle is located approximately 10.574 m to the front right of the ego car is driving in the same direction </ref>` `<box> (881, 465), (913, 687) </box>` `<ref> In 'CAM_LEFT', vehicle is located approximately 7.673 m to the back left of the ego car is driving in the opposite direction </ref>` `<box> (197, 476), (509, 671) </box>`

Ego State

Your current speed is 6.238167388988819 m/s. Your current steering value is -0.18778696061027783.

Reasoning

There is a vehicle on the front right of the ego car at a distance of approximately 10.574 meters, which is close enough to warrant attention as it is within the same lane or close to it. The relative coordinates show that this vehicle is mostly in the right lane, not directly in the ego lane. Given the current steering value is negative, we should also be aware of objects on the left side, but since the vehicle in the left lane is moving in the opposite direction and no other details require immediate attention, it does not influence the decision-making in this scenario. *Since the vehicle in the right lane is relatively close and any sudden lane change into the ego lane could present a risk, it would be prudent to slow down to maintain a safe following distance and be ready to react if necessary.* There are no red traffic lights or stop signs mentioned, so those rules do not apply.

Decision

DC



Thank You for Your Attention

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