Neural Rendering for Safety-critical Autonomous Driving Simulation

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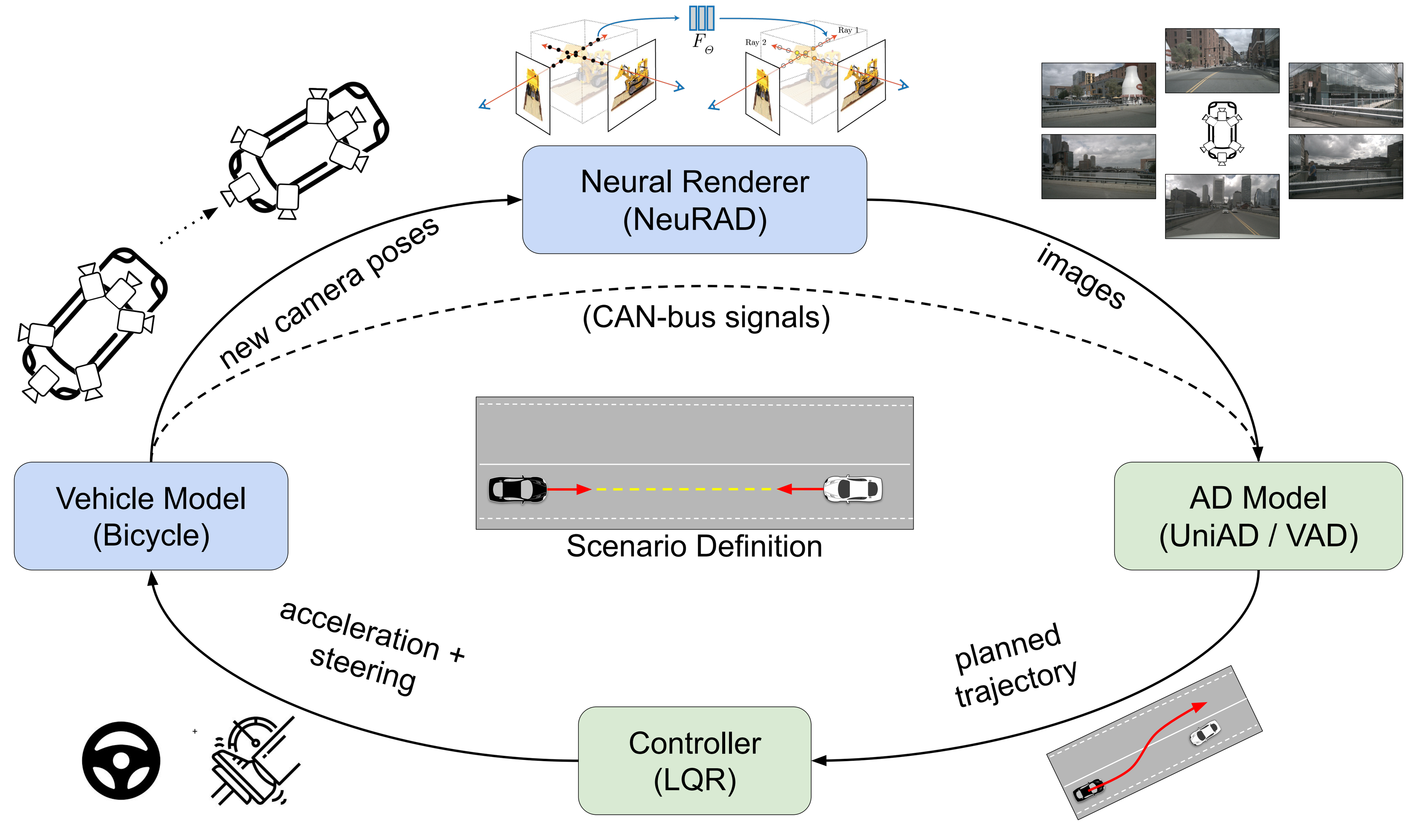
TLDR

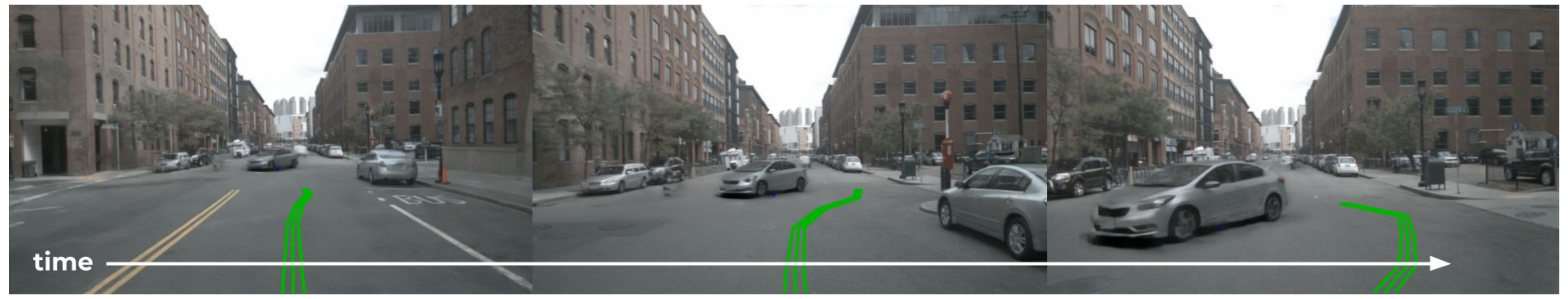
We **leverage NeRFs** for autonomous driving **to realistically simulate safety-critical scenarios** from a sequence of real-world data **and evaluate end-to-end AD systems in closed-loop.**

Photorealistic closed-loop simulation

Our closed-loop simulator iteratively performs four steps:

1. The **Neural Renderer** generates high-quality sensor data. The renderer is trained on a sequence of real-world driving data.
2. The **AD Model** predicts a future ego-vehicle trajectory given the rendered camera input and the ego-vehicle state.
3. The **Controller** converts the planned trajectory to a set of acceleration and steering signals.
4. The **Vehicle Model** propagates the ego-state forward in time, based on the control inputs.





Contributions

★ Release open source framework for **photorealistic closed-loop simulation** for autonomous driving

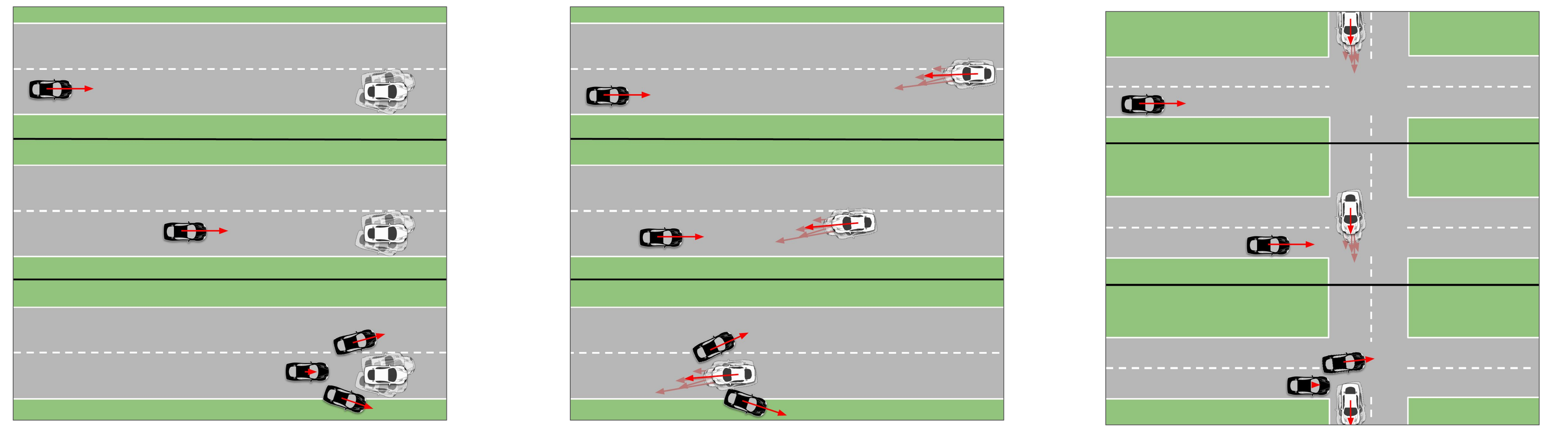
★ **Construct safety-critical scenarios**, inspired by the industry standard Euro NCAP, that cannot safely be collected in the real world.

★ **Novel evaluation protocol** that focuses on collisions in closed-loop rather than displacement metrics in open-loop.

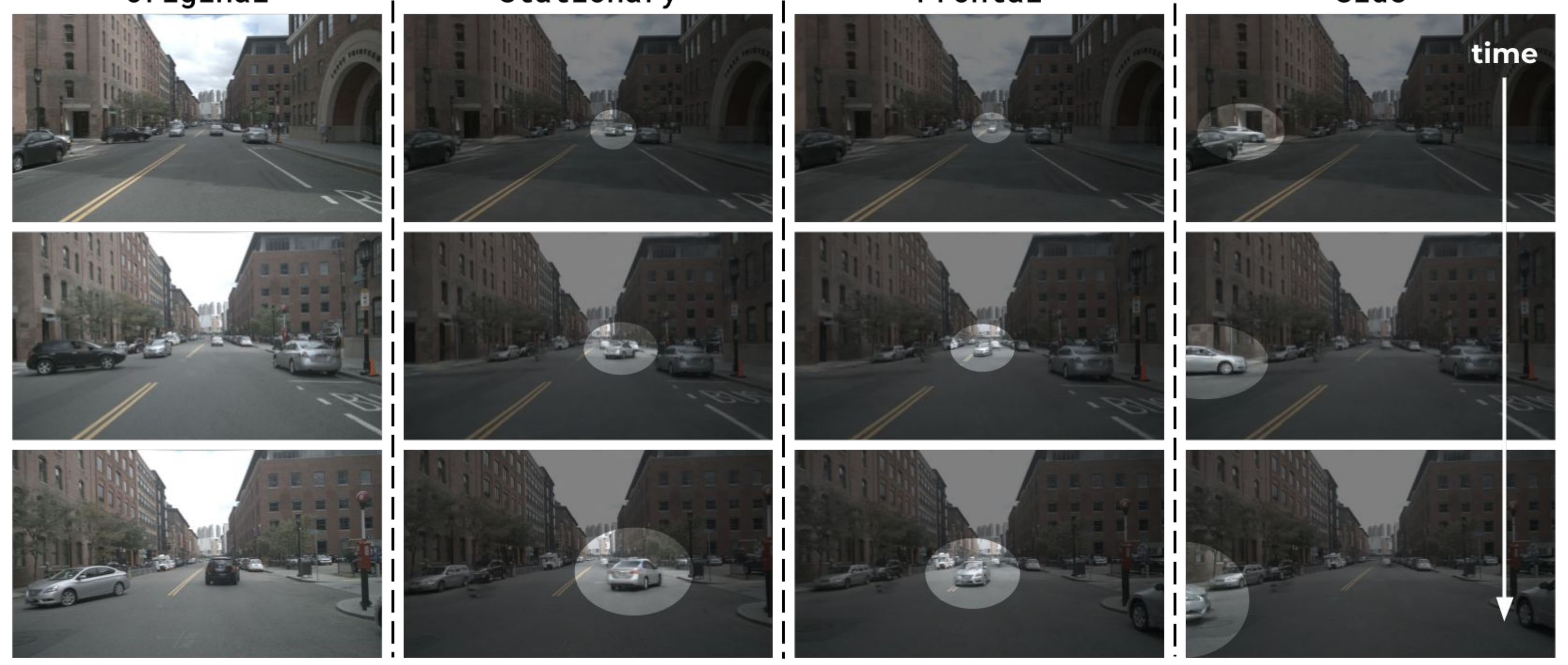
★ Show that two SotA **end-to-end planners fail severely** in our safety-critical scenarios despite accurately perceiving the environment.

Construct safety-critical scenarios in the wild

With inspiration from the industry standard EuroNCAP, we define three safety-critical scenario types…



…and then we use neural rendering to turn a nominal driving scene into multiple challenging and interesting safety-critical scenarios



End-to-end planners fail severely in safety-critical scenarios

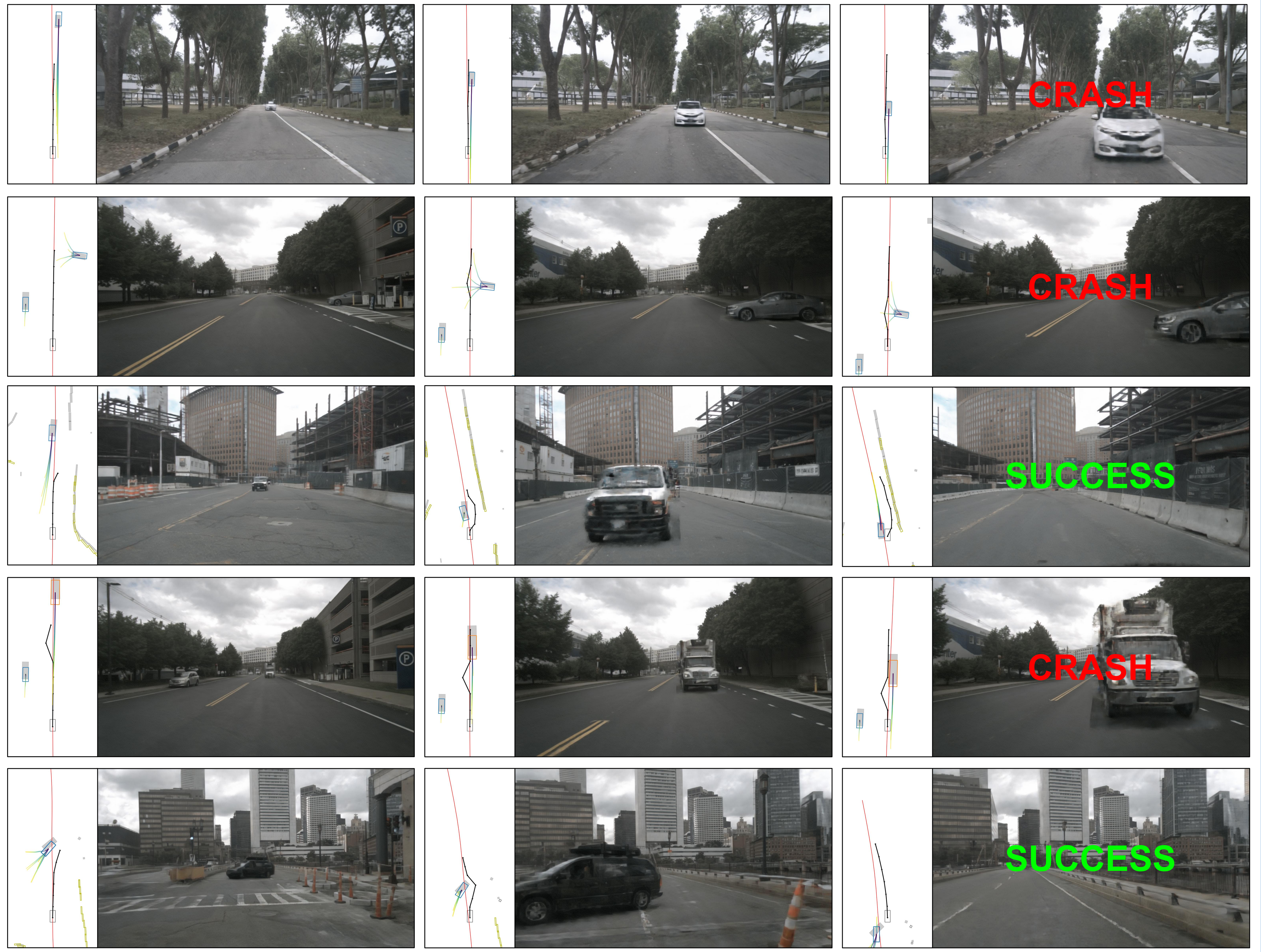
We evaluate two end-to-end driving models and find that while they perceive the objects correctly they fail to take actions to avoid collision

Model	Post-proc.	NeuroNCAP Score ↑				Collision rate (%) ↓			
		Avg.	Stat.	Frontal	Side	Avg.	Stat.	Frontal	Side
Base-U	-	2.65	4.72	1.80	1.43	69.9	9.6	100.0	100.0
Base-V	-	2.67	4.82	1.85	1.32	68.7	6.0	100.0	100.0
UniAD	x	0.73	0.84	0.10	1.26	88.6	87.8	98.4	79.6
VAD†	x	0.66	0.47	0.04	1.45	92.5	96.2	99.6	81.6
UniAD†	✓	1.84	3.54	0.66	1.33	68.7	34.8	92.4	78.8
VAD	✓	2.75	3.77	1.44	3.05	50.7	28.7	73.6	49.8

†Corresponds to the model's original setting.

$$\mathrm{NNS} = \begin{cases} 5.0 & \text{if no collision} \\ 4.0 \cdot \max(0, 1 - v_i/v_r) & \text{otherwise} \end{cases}$$

Reference Trajectory · Planned Ego Trajectory · Predicted Future Trajectory · Ego Vehicle · Predicted Objects · GT Objects



For more information, code, and examples, visit our project page at
research.zenseact.com/publications/neuro-ncap

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