

UniSim: A Neural Closed-Loop Sensor Simulator

Ze Yang*, Yun Chen*, Jingkang Wang*, Sivabalan Manivasagam*,
Wei-Chiu Ma, Anqi Joyce Yang, Raquel Urtasun

<https://waabi.ai/unisim/>



Motivation: Closed-Loop Sensor Simulation

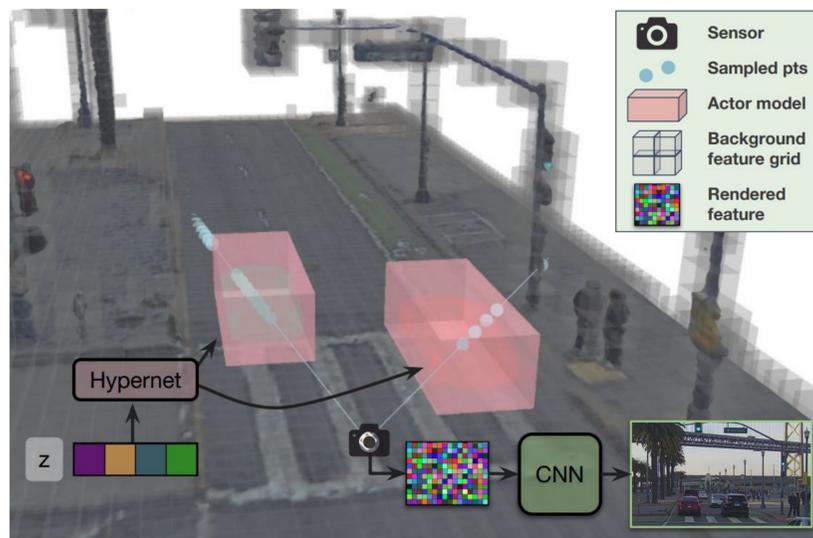
- **Long-tail scenarios** are critical for robot evaluation
- **Closed-loop simulation** allows the autonomy system to reactively interact with the environment, enabling testing self-driving at large-scale with low-cost and low-risk.
- **Existing methods** are not scalable due to manual creation of assets, lack diversity due to the limited number of scenes and assets available, and lack realism due to domain gap
- **UniSim:** build digital twin from real world data and test autonomy in closed-loop for insight and development



Method: Building Digital Twin

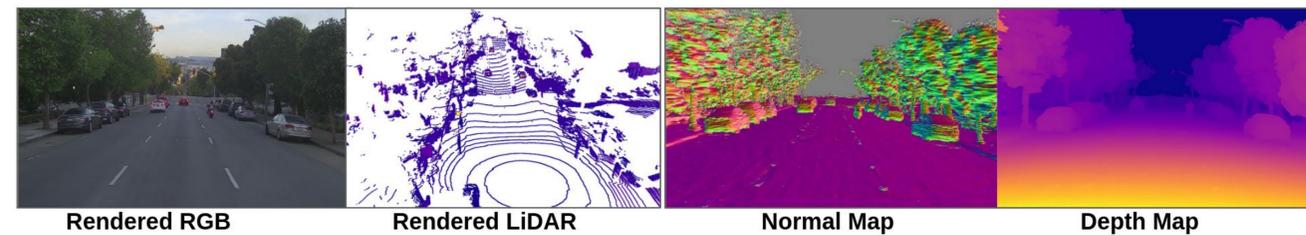
Scene is decomposed into **static background** and **dynamic actors**

1. Static background is modelled with sparse hash grid
2. Dynamic actors' representation are generated by a hyperNet
3. Volume render feature map for each ray
4. A CNN upsamples the rendered feature to produce output



Capabilities

Reconstruction: manipulable digital twin is reconstructed from collected data



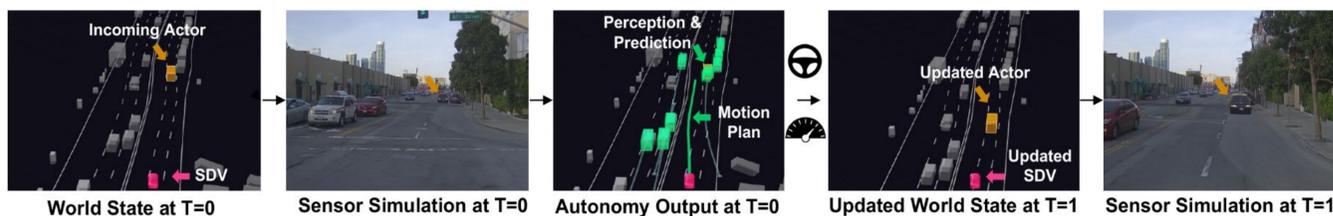
Scene manipulation: manipulate actors behavior to create new scenarios



SDV control: control SDV reaction or sensor placement



Closed-loop simulation: create counterfactual scenarios and let the autonomy system reactively interact with the environment

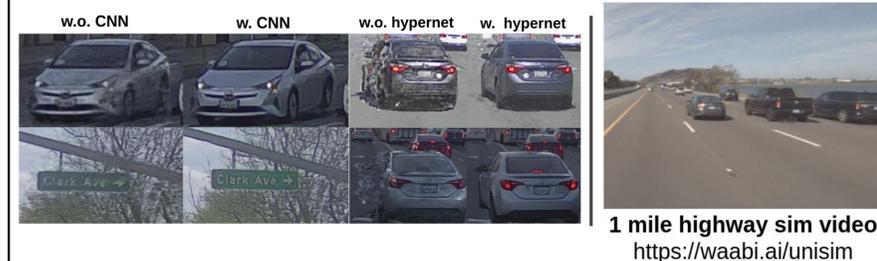


Results

Visual Realism



Ablation



Autonomy Evaluation: UniSim is "realistic" from autonomy perspective and can improve autonomy performance

Method	Log Replay		Lane Shift		Instant-NGP	FVS	Ours
	Real2Sim	Sim2Real	Real2Sim	Sim2Real			
FVS	36.9	38.7	30.3	32.2	32.4	39.2	41.4
Instant-NGP	22.6	34.0	18.1	26.5	40.1	41.1	42.9
Ours	40.2	39.9	37.0	37.1			

Augmenting with simulation, mAP.

	Det. Agg.	↑ Pred. ADE	↓ Plan Cons.
FVS	0.80	2.35	6.15
Instant-NGP	0.42	3.24	13.44
Ours	0.82	1.68	6.09

Detection domain gap, mAP. Real2Real = 40.9

Open-Loop Real2Sim Autonomy Evaluation

Limitations

- Lighting and animation is not modelled
- Artifacts when camera move far away from training view
- Rendering speed is not real-time