

LiDAR Simulation Components Motivation: Realistic End-to-End Simulation (A) Pulse Effects • Simulation is critical for scalable self-driving development • End-to-end analysis is necessary, but needs sensor input Naive Raycast Real Sensor simulation realism is challenging to measure Main contributions: Extra points increase domain gap. 1. novel methodology for evaluating a simulator's domain gap 2. analysis of what is relevant for realistic LiDAR simulation Right Left Center s around object boundaries need to be modelled. Sim **Ghost reflections** may also (Left) Example reconstructed digital twin used in our analyses. impact the autonomy system.



(Right) Simulated and Real LiDARs.

Results: LiDAR Phenomena

#	\mathbf{DropP}	AddE	AddP	ModP	Prediction minADE↓	Planning PD@5s↓
1					1.74	3.22
02	\checkmark				1.87	3.30
3		\checkmark			1.58	2.71
4			✓		1.43	3.21
5		1	1		1.35	2.50
6				[0, 200]	0.98	1.80
7	1		1		1.46	3.22
8	\checkmark			[0, 200]	0.42	0.92
9			✓	[0, 200]	0.93	1.69
10		~	~	[0, 200]	0.93	1.69
oracle	1	✓	✓	1	0.00	0.00

Prediction minADE = min absolute displacement error **Planning PD** = plan divergence, L2 error between output waypoints

Towards Zero Domain Gap: A Comprehensive Study of Realistic LiDAR Simulation for Autonomy Testing

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Summary & Outlook

(A) Pulse Phenomena

Secondary returns should not be ignored

- Future LiDAR rendering approaches need to model unreturned rays
- Material modeling should be coupled with better geometry for best results

(B) Temporal Effects

Motion blur more important than rolling shutter

• Rolling shutter less important as simulator output is always compensated, and autonomy expects motion-compensated input

Off-the-shelf + reconstructed assets is best

Off-road background is surprisingly important for realism



Analysis Methodology

- Paired setting: real data + re-simulated data
- (A) Pulse effects: Selectively transfer real LiDAR effects (e.g. dropped rays) using oracles
- (B) Temporal effects: Ablated from the base raycasting engine
- (C) Asset fidelity: Also ablated from the engine.

