Multiverse Transformer:
Advancing Closed-Loop Multi-Agent Simulation with Generative Model

Yu Wang[1], Tiebiao Zhao[2], Fan Yi[1], Guangzhi Cao[3]

[1]Pegasus, [2]Nvidia, [3]ZDrive.ai

Problem Formulation

- Waymo Open Sim Agents Challenge (WOSAC) 2023
  - Given scene context, including map and past positions of the agents (both world agents and ADV), simulate states of the agents at 0.1s interval for the upcoming 80 timesteps
- The Constraints
  - Simulator must be closed-loop, and run in autoregressive manner
  - World agents and ADV must be conditionally independent, i.e., ADV component can be replaced with any arbitrary policy or planner
- Our Method: adapts transformer-based motion predictor for multi-agent simulation
  - Agent-centric
  - Autoregressive
  - Closed-loop

Training

- The training samples are generated to accommodate variable lengths of past history, as opposed to adhering to a fixed length of 1.1s
- We use L1 loss for regressing the agent velocity and heading angles, and the Gaussian regression loss based on the negative log-likelihood loss to maximize the likelihood of ground-truth trajectory
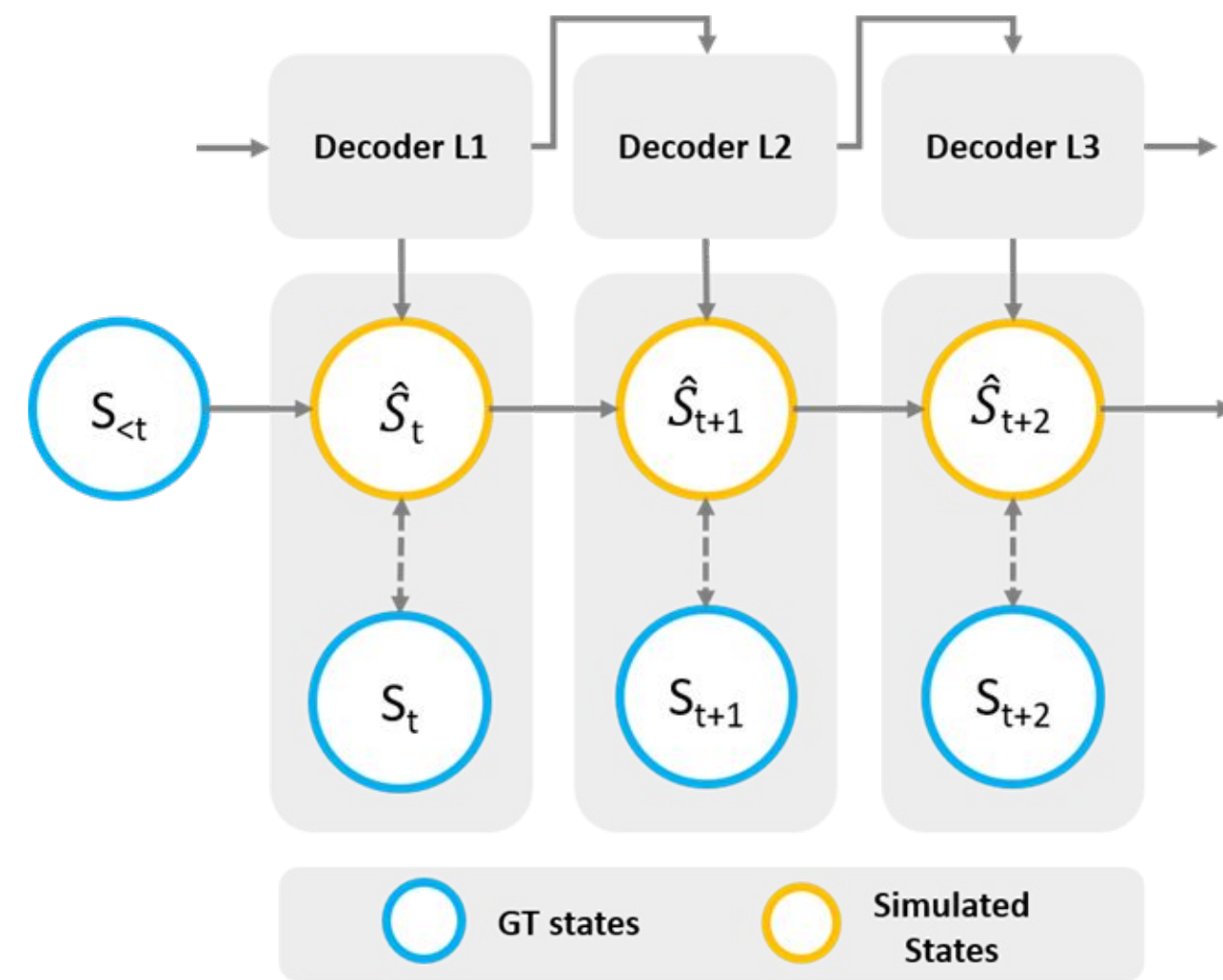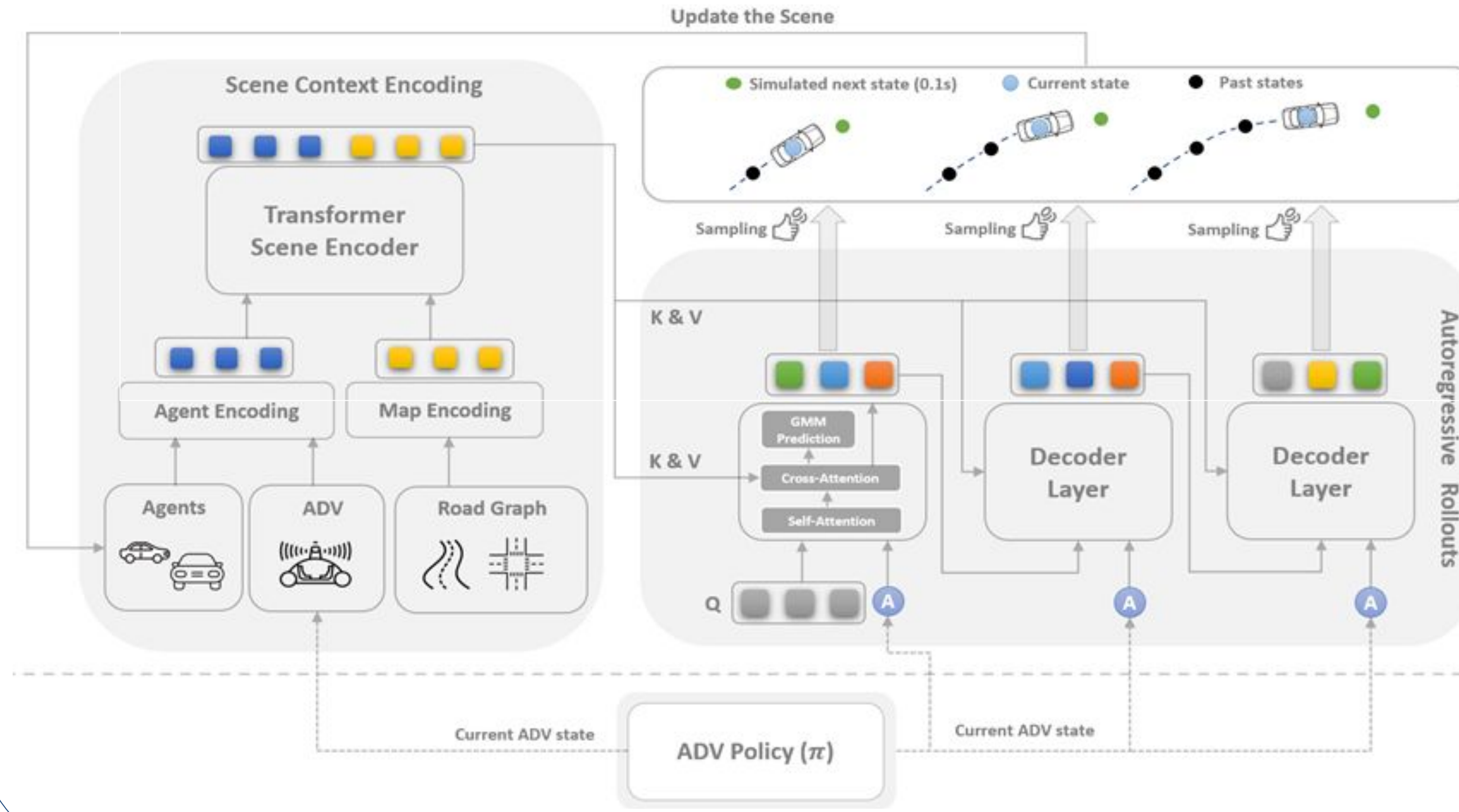

End-to-end training, with loss calculated at each timestep
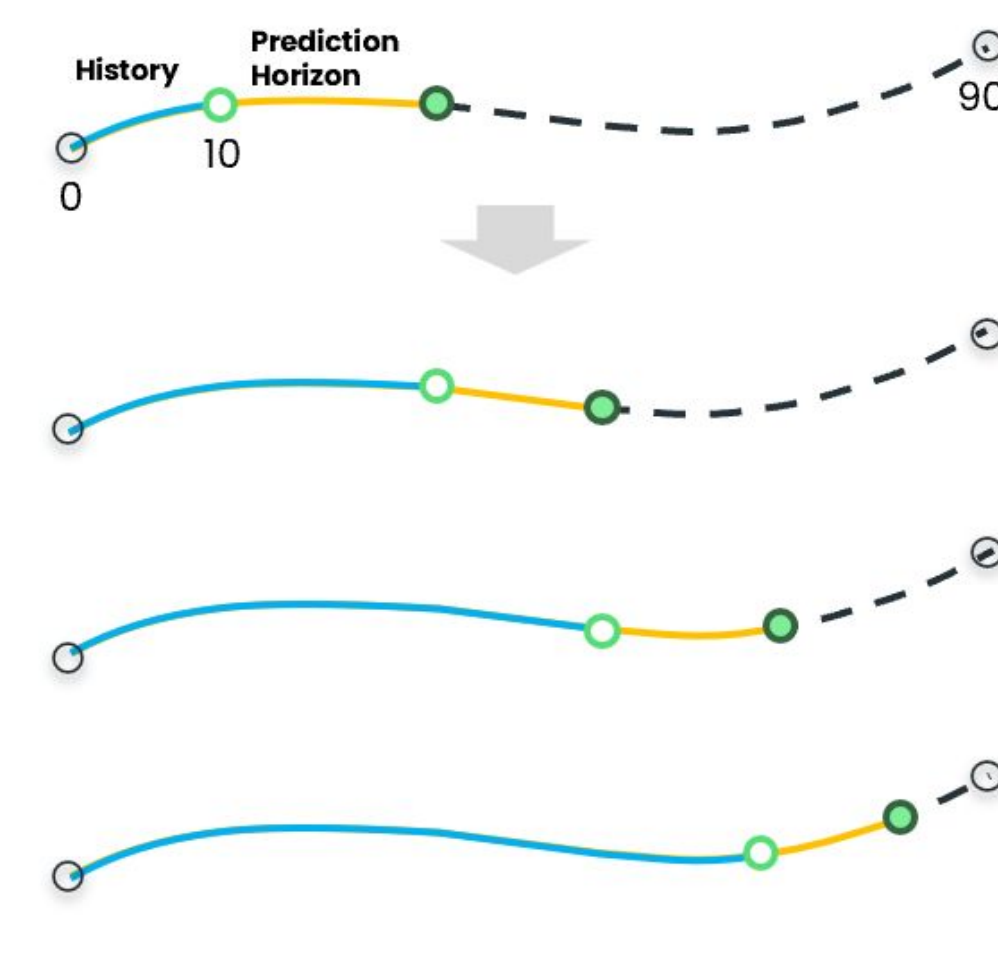
Randomly pick a point to separate the trajectory to history and future components

## Main Architecture

Inference

- Receding prediction horizon: prediction horizon is 1s, but only the waypoint of the initial 0.1s is utilized, with the remaining prediction being discarded.
- Top-K sampling applied at periodic intervals to strike a balance between realism and diversity
- Variable-length history to aggregate the past trajectory overtime
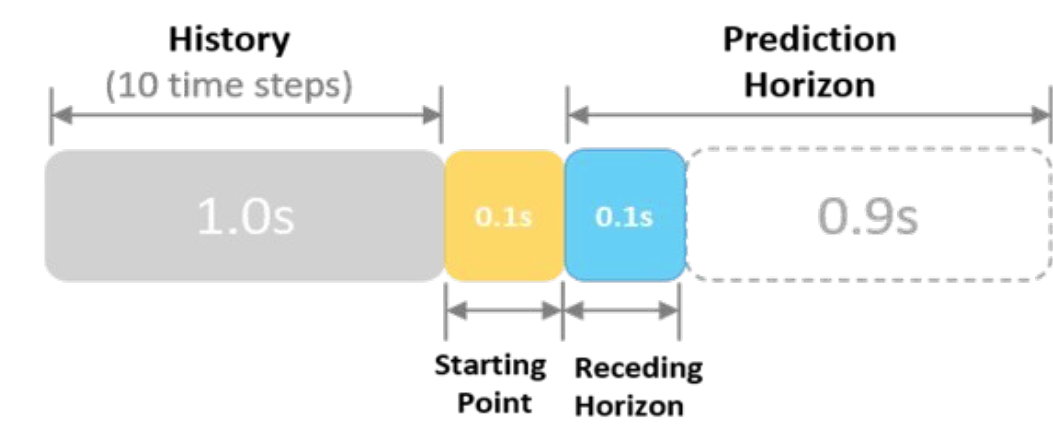
Receding Prediction Horizon
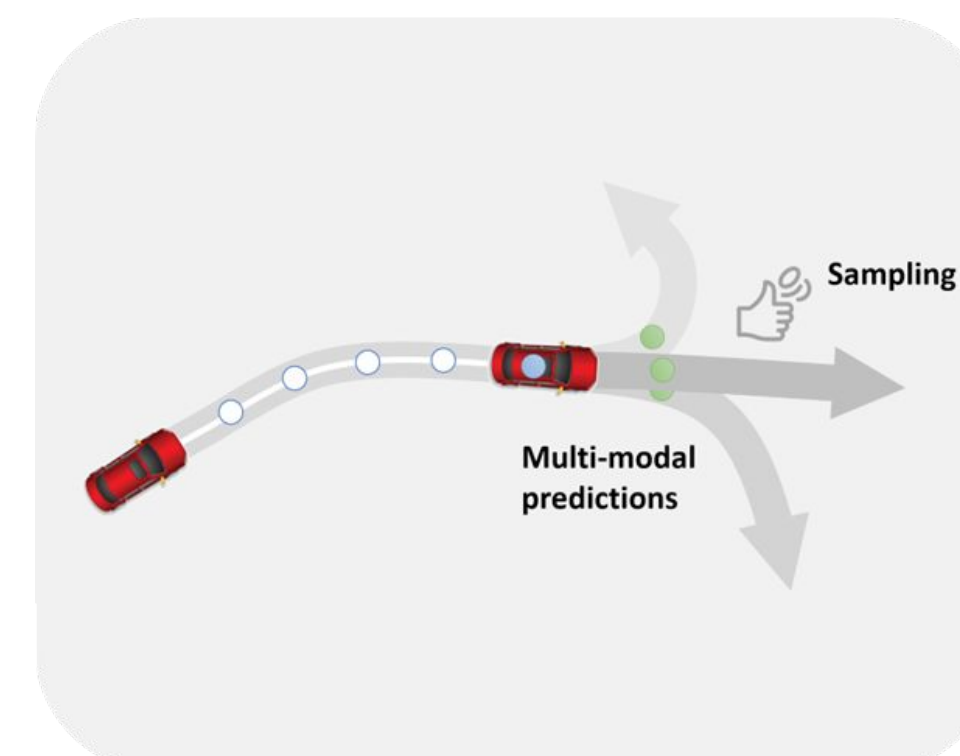
Top-K Sampling
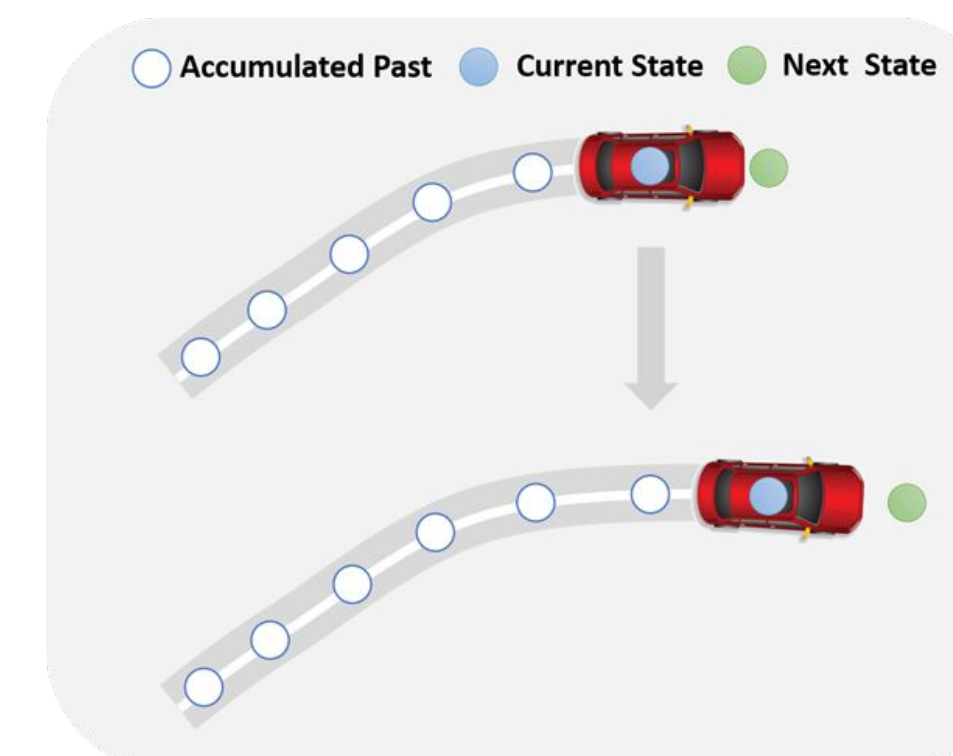
Aggregating new waypoint to the past trajectory

Results

WAYMO LEADERBOARD	META METRIC REALISM	KINEMATIC				INTERACTIVE			MAP		minADE (↓)
		LINEAR SPEED	LINEAR ACCEL.	ANG. SPEED	ANG. ACCEL.	DIST. TO OBJ.	COLLISION	TTC	DIST. TO ROAD	OFFROAD	
MVTE (ours)	**0.5168**	0.4426	0.2218	**0.5353**	**0.481**	**0.382**	0.4509	**0.832**	**0.6641**	**0.6409**	1.677
MVTA (ours)	0.5091	0.4365	0.22	0.533	0.4805	0.3729	0.4359	0.8298	0.6545	0.6288	1.8698
MTR+++	0.4697	0.4119	0.1066	0.4838	0.4365	0.3457	0.4144	0.7969	0.6545	0.577	1.6817
CAD	0.4321	0.3464	**0.2526**	0.4327	0.311	0.33	0.3114	0.7893	0.6376	0.5397	2.3146
multipath	0.424	0.4318	0.2304	0.0193	0.0355	0.3493	**0.4854**	0.8111	0.6372	0.613	2.0517
sim.agents.tutorial	0.3941	0.3143	0.1738	0.4785	0.4631	0.2641	0.2671	0.7709	0.5575	0.4111	3.6198
QCNeXt	0.392	**0.4773**	0.2424	0.3252	0.1987	0.3759	0.3244	0.7569	0.6099	0.36	**1.083**
sim.agents.tutorial	0.3201	0.3826	0.0999	0.0318	0.0391	0.2909	0.336	0.7549	0.5251	0.3804	3.108
linear.extrapolation.baseline.tutorial	0.2576	0.0745	0.1659	0.0187	0.0348	0.2221	0.2211	0.7551	0.479	0.3352	5.7148

V1 Leaderboard	Realism Meta metric	Kinematic metrics	Interactive metrics	Map-based metrics	minADE (↓)	Submission Date
MVTE (ours)	**0.6448**	0.4202	0.7666	0.8387	1.6770	5/23/2023
MVTA (ours)	0.6361	0.4175	0.7543	0.8253	1.8698	5/22/2023
MTR+++	0.6077	0.3597	0.7334	0.8266	1.6817	5/23/2023
CAD	0.5314	0.3357	0.5643	0.7782	2.3146	5/23/2023
multipath	0.4766	0.1792	0.6380	0.6866	2.0517	5/23/2023
QCNeXt	0.4538	0.3109	0.5654	0.5051	**1.0830**	5/21/2023
sim agents tutorial	0.4202	0.3574	0.4184	0.5052	3.6198	5/23/2023
sim agents tutorial	0.3268	0.1384	0.4473	0.4118	3.1080	5/16/2023
linear extrapolation tutorial	0.3059	0.0735	0.4271	0.4559	7.5148	5/9/2023
Trajeglish	0.6437	0.4157	**0.7816**	0.8213	1.6146	1/10/2024
MTR_E	0.6348	0.4180	0.7416	**0.8400**	1.6561	6/25/2023
VPD-Prior	0.6315	**0.4261**	0.7233	0.8330	1.3400	2/14/2024
Trajeglish	0.6078	0.4019	0.7274	0.7682	1.8719	11/27/2023
SceneDMF	0.5821	0.4244	0.6761	0.7056	2.4186	9/14/2023
PredSim	0.5663	0.3967	0.6545	0.7133	2.3984	2/8/2024
SceneDM	0.5655	0.4245	0.6438	0.6816	2.4326	9/22/2023
G-net	0.5585	0.4162	0.6255	0.6887	3.7138	6/20/2023
sim agents tutorial	0.5409	0.3886	0.5935	0.7033	2.0342	7/13/2023
PredSim	0.5320	0.3923	0.5557	0.7147	2.9100	12/9/2023
sim agents tutorial	0.5248	0.3738	0.5509	0.7190	2.8504	7/14/2023