KnowMoformer: Knowledge-Conditioned Motion Transformer for Controllable Traffic Scenario Simulation

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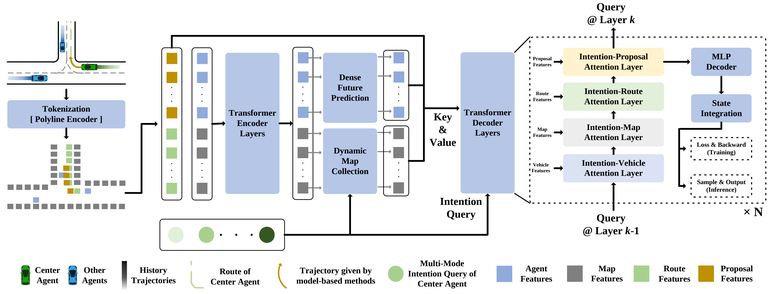
Motivation and Approach

Simulation is of crucial importance for development and testing of autonomous vehicles. To minimize sim-to-real gap, the simulator should generate realistic scenarios.

In this work, we introduce **Know**ledge-Conditioned **Mo**tion Trans**former** (KnowMoformer), integrating long-term routes and model-based actions to the neural network, to make model offer both of realism and controllability.

KnowMoformer Framework



The architecture of our KnowMoformer. The input of model is time-series of states of all agents, spatial information of map, route and IDM states of the agent. The output is the distribution of predicted trajectories of interested agent with GMM.

The learning objective of driving simulator is:

$$\min_{\theta} D_{KL}(\pi(x_{i,T}|X^i_{0:T-1};m)||\pi_\theta(x_{i,T}|X^i_{0:T-1};m)) \tag{1}$$

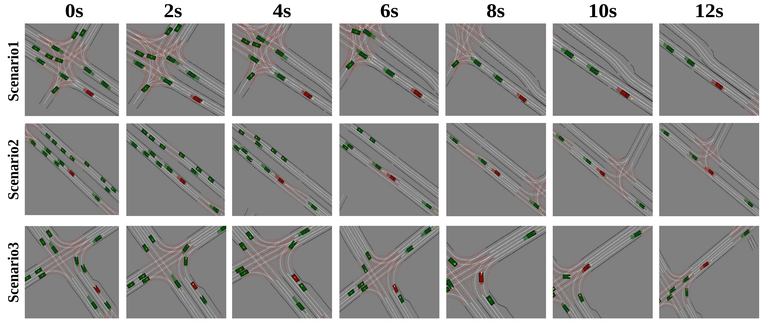
The loss function is:

$$\min_{\theta} L_{NLL} + \lambda_h L_h + \lambda_v L_v + \lambda_{dense} L_{dense} \tag{2}$$

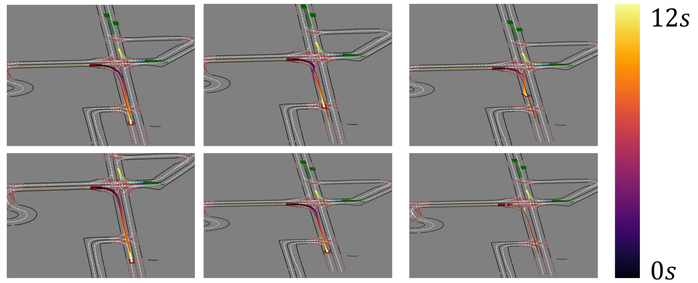
$$L_{NLL} = -E_{\left\{X^i, x^{GT}_{i,T}\right\}\sim P_{real}}[log(\pi^c_\theta(x^{GT}_{i,T}|X^i, m, r_i, I_i))] \tag{3}$$

other terms are regression terms for different heads.

Qualitative Results

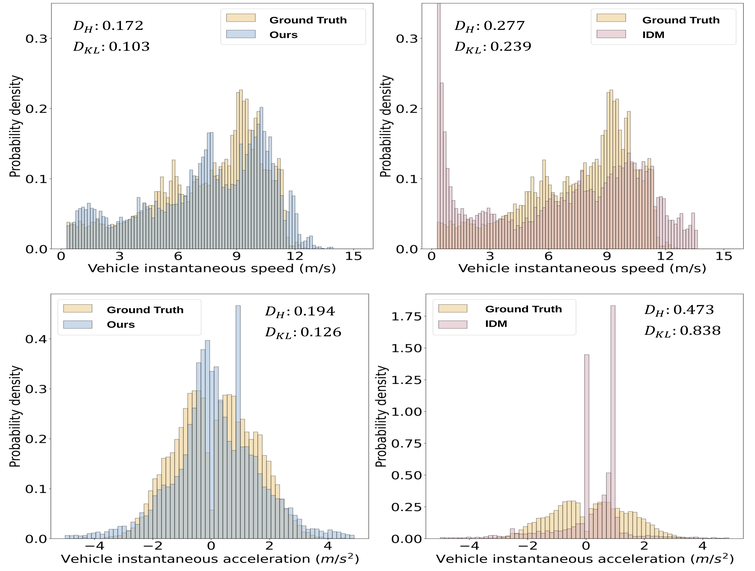


During inference, we use the first 5 steps (0.5s) of the output to ensure that the simulator is interactive. At next unroll step, the input trajectory of each agent is updated by concatenating with last inference results temporally.



Given a route as conditional input, diverse but route-aligned behaviors can be sampled from the learned distribution, demonstrating the effectiveness of intention-route attention.

Quantitative Results



	minADE ↓	KL_{vel} ↓	KL_{acc} ↓	COLLISION ↓	OFFROAD ↓
IDM	1.059	0.239	0.838	0.0098	0.389
MTR	0.753	1.277	0.184	0.0134	0.442
MTR+Route	0.549	0.973	0.421	0.0218	0.397
MTR+Proposal	0.761	0.475	0.134	0.0337	0.414
Ours	0.682	0.103	0.126	0.0117	0.382

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