Micro-To-Macro Traffic Modelling with Machine Learning

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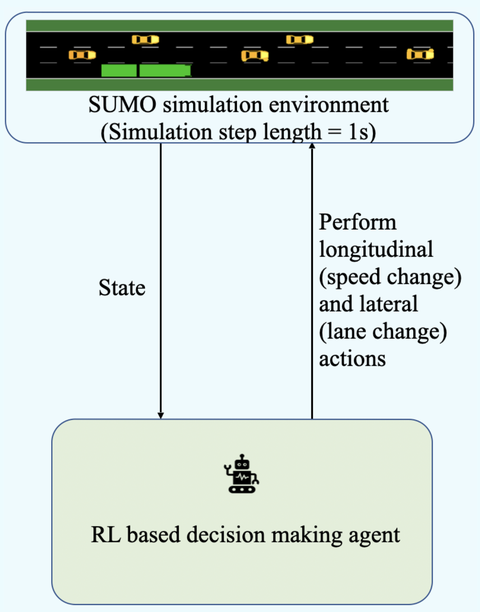
Background

This project aims to develop novel machine learning based frameworks to model complex real-world traffic scenarios involving heavy-duty vehicles. These models will be utilized for informed decision-making in Autonomous Vehicles and Advanced Driver Assistance Systems (ADAS) at Volvo.

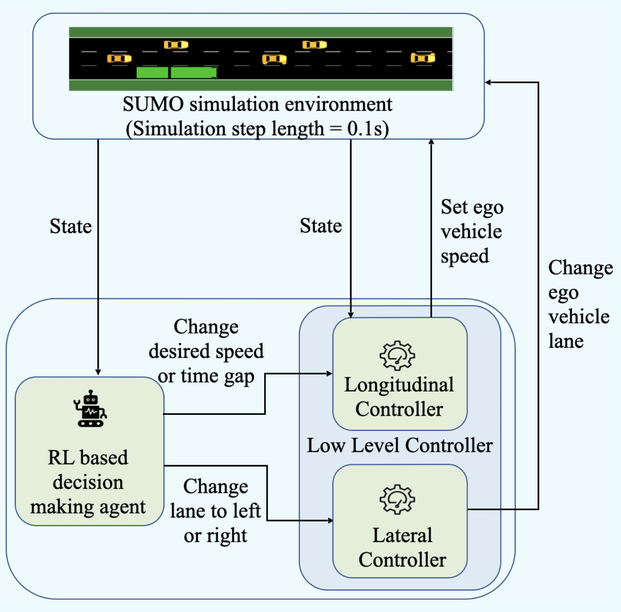
Safe & Smart Decision Making: Merging ML with Physical Models

- Tactical decision making for ACC and lane changes in a highway scenario simulated in SUMO platform, with Reinforcement Learning (RL) techniques.
- Mitigate the risks of fully relying on RL methods for safety-critical decisions, by combining them with physical models and separating high and low-level decisions making.

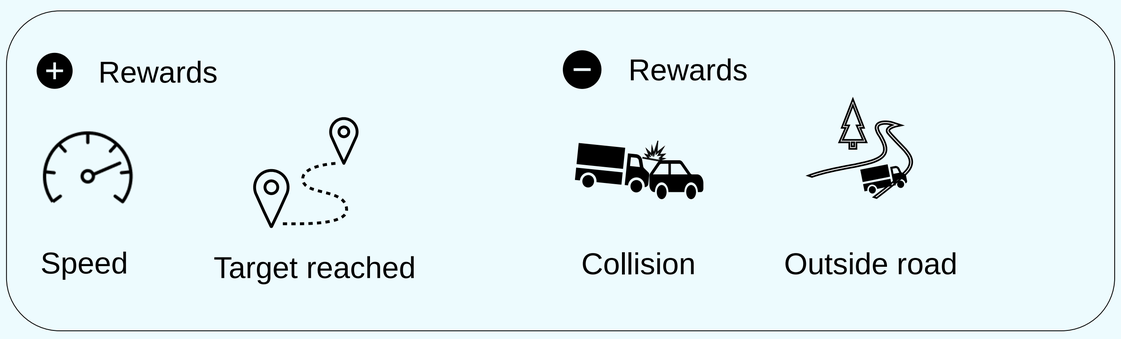
Baseline Architecture



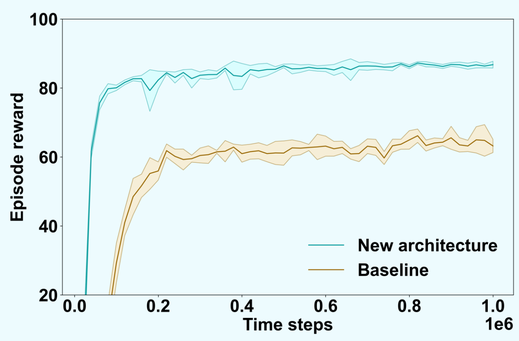
Proposed Architecture



Safety Focused Reward Function



Key Results



Training reward curve

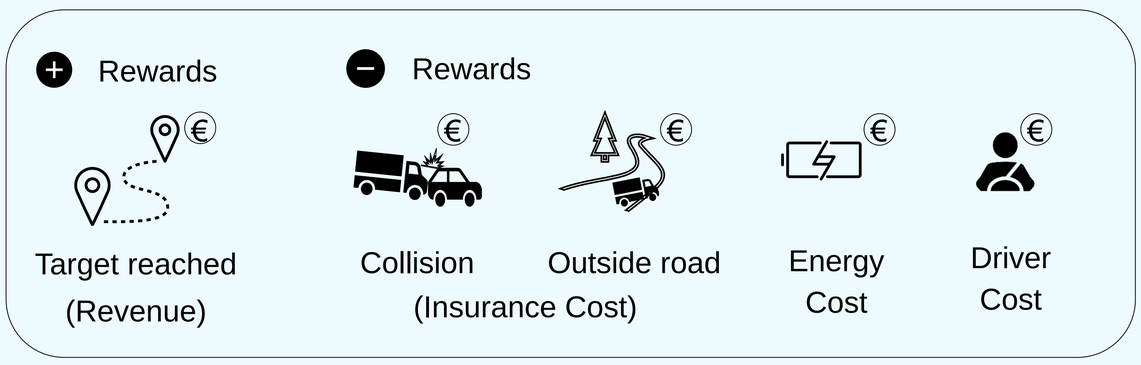
Evaluation Metric	Baseline	New
Reached target successfully	**70.6 %**	**97.8 %**
Driven successfully, but not reached target within max steps	0%	0.6 %
Terminated by collision or driving outside road	**29.4 %**	**1.6 %**
Average speed	19.43 m/s	18.56 m/s
Average distance travelled	1668 m	2178 m

Validation results

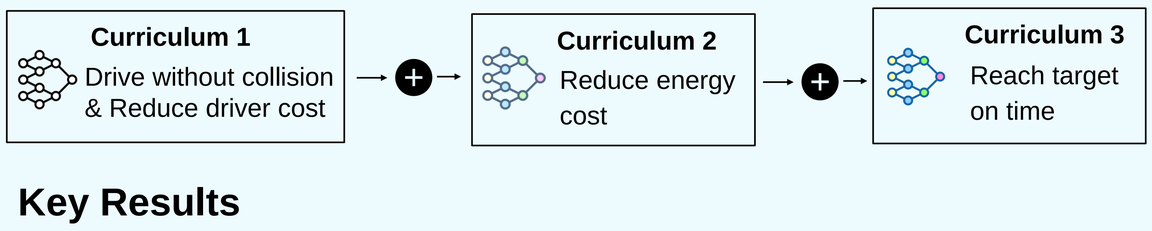
Cost-Efficient Decision Making: Optimizing TCOP

We design a realistic reward function based on the Total Cost of Operation (TCOP) of the truck to guide the RL agent towards optimal and cost-efficient driving strategy.

TCOP Based Reward Function



Curriculum Reinforcement Learning (CRL)

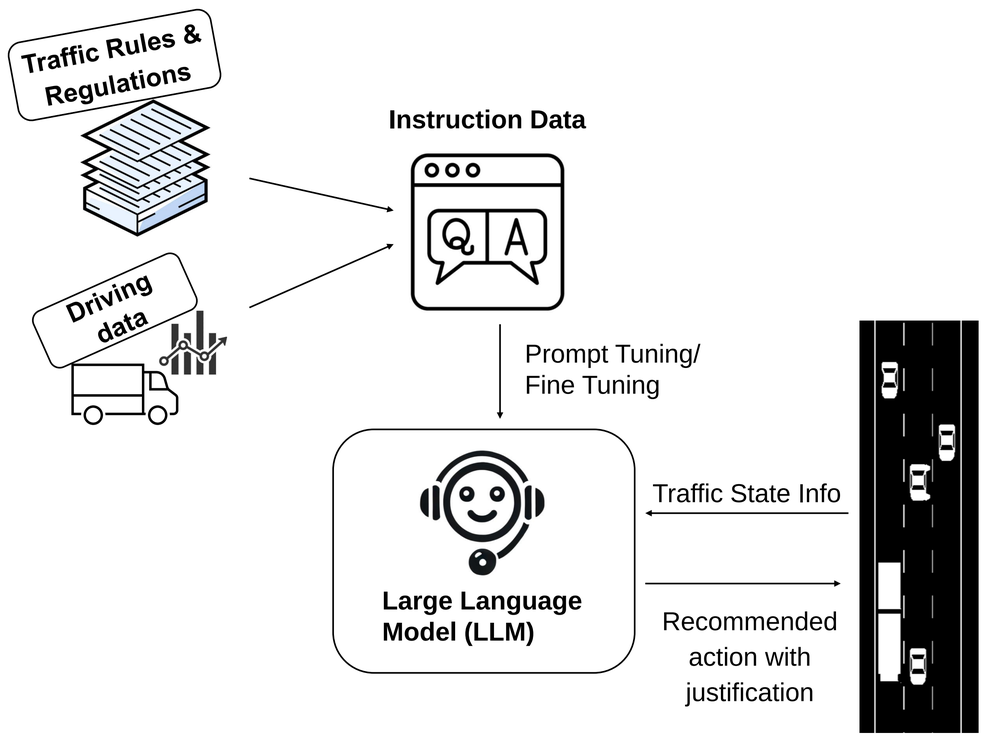


Key Results

- Convergence challenges observed while using the complex reward function with real money values.
- CRL approach showcase comparable performance as non-CRL approach, while normalizing reward components improves performance.

Decision Making with Reasoning: How to Utilize LLMs ?

In the ongoing work, we investigate how to make use of natural language processing and reasoning capabilities of LLMs to solve complex tactical decision making.



References

- D. Pathare, L. Laine and M. H. Chehreghani, "Improved Tactical Decision Making and Control Architecture for Autonomous Truck in SUMO Using Reinforcement Learning," 2023 IEEE International Conference on Big Data
- D. Pathare, L. Laine and M. H. Chehreghani, “Tactical Decision Making for Autonomous Trucks by Deep Reinforcement Learning with Total Cost of Operation Based Reward”, arXiv:2403.06524, 2024 (under review)

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