Learning Robustness Degrees of Traffic Rule Predicates in Signal Temporal Logic

Background

Autonomous vehicles need to comply with traffic rules so that they cannot be held liable for traffic accidents. To formalize the traffic rules in a precise and machine-readable manner, temporal logic languages are often used. Linear temporal logic (LTL) [1, 2] and metric temporal logic (MTL) [3] provide Boolean values for traffic rule satisfaction or violation. To better evaluate continuous dynamics, signal temporal logic (STL) [4] extends the MTL to specify real-valued solutions with the quantitative *robustness degree* [5], which indicates how far is a signal from satisfying a specification. However, the robustness degrees of various predicates are nontrivial to determined for traffic rule specifications [6]. To solve this problem, one solution is to use end-to-end learning based on the real traffic dataset, e.g., the Gaussian mixture regression model as in [7]. We address exactly this problem for which a satisfying solution does not yet exist in the literature.

Description

Different robustness functions of predicates influence the robustness measurement of temporal logic. Therefore, the aim of this thesis is to devise a regression model for learning the robustness degrees of predicates in STL, which is based on the ground-truth dataset. To achieve this, we can sample a finite set of actions for the ego vehicle to simulate a series of trajectories starting from the current state. Afterward, the vehicle's state is regarded as the feature vector, and we set the number of violations for each state as the label vector, i.e., the state/violation pairs are used for regression analysis. Based on the regression result offline, we can assign the robustness degree for each predicate based on the given vehicle's state online. The larger the robustness degrees are, the harder the predicate can be violated. Moreover, the results should be demonstrated in CommonRoad[1] [8], which is a collection of composable benchmarks for motion planning on roads.

[1] https://commonroad.in.tum.de/

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Research project:
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BA/SA

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Motion Planning, Traffic Rules, Machine learning

Programming language:
Python

Required skills:
Advanced programming skill, able to work independently, familiar with machine learning approaches

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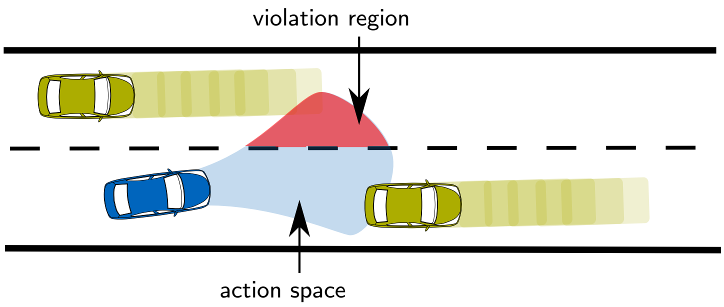

Action space of the ego vehicle and the violation region of predicate in_same_lane.

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Tasks

- Literature review of works related to regression analysis, temporal logic
- Familiarizing with the current robustness function definition in [6] and the existing traffic rule monitor in CommonRoad platform
- Implementing and comparing different methods to build the regression model based on the HighD dataset [9]
- Evaluation of the developed approach on CommonRoad scenarios
- Comparing the results with those obtaining from the current definition of robustness functions
- Documentation of codes and other related materials

References

[1] A. Rizaldi, F. Immler, B. Schürmann, and M. Althoff, "A formally verified motion planner for autonomous vehicles," in *Proc. of the Int. Symposium on Automated Technology for Verification and Analysis*, pp. 75–90, 2018.

[2] K. Esterle, L. Gressenbuch, and A. Knoll, "Formalizing traffic rules for machine interpretability," in *Proc. of the IEEE Connected and Automated Vehicles Symposium*, pp. 1–7, 2020.

[3] S. Maierhofer, A.-K. Rettinger, E. C. Mayer, and M. Althoff, "Formalization of interstate traffic rules in temporal logic," in *Proc. of the IEEE Intelligent Vehicles Symposium*, pp. 752–759, 2020.

[4] O. Maler and D. Nickovic, "Monitoring temporal properties of continuous signals," in *Formal Techniques, Modelling and Analysis of Timed and Fault-Tolerant Systems*, pp. 152–166, 2004.

[5] G. E. Fainekos and G. J. Pappas, "Robustness of temporal logic specifications for continuous-time signals," *Theoretical Computer Science*, vol. 410, no. 42, pp. 4262–4291, 2009.

[6] L. Gressenbuch and M. Althoff, "Predictive monitoring of traffic rules," in *Proc. of the IEEE Int. Conf. on Intelligent Transportation Systems*, 2021.

[7] C. Huang, P. Hang, Z. Hu, and C. Lv, "Collision-probability-aware human-machine cooperative planning for safe automated driving," *IEEE Transactions on Vehicular Technology*, 2021.

[8] M. Althoff, M. Koschi, and S. Manzinger, "CommonRoad: Composable benchmarks for motion planning on roads," in *Proc. of the IEEE Intelligent Vehicles Symposium*, pp. 719–726, 2017.

[9] R. Krajewski, J. Bock, L. Kloeker, and L. Eckstein, "The highd dataset: A drone dataset of naturalistic vehicle trajectories on German highways for validation of highly automated driving systems," in *Proc. of the IEEE Int. Conf. on Intelligent Transportation Systems*, pp. 2118–2125, 2018.