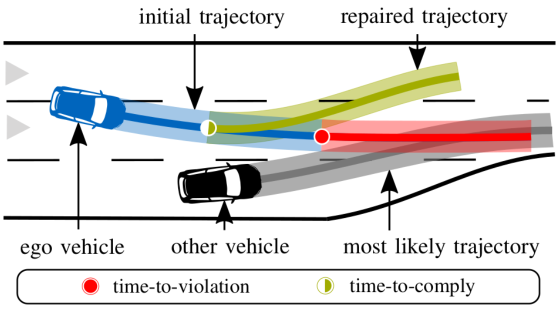
Worst-case Analysis of the Time-To-Comply Using Reachable Sets

Background

One of the barriers in developing autonomous driving is the liability problem for traffic accidents. This issue can be addressed, e.g., by unambiguously formalizing traffic rules for autonomous vehicles. If autonomous vehicles always comply with traffic rules, they cannot be held liable for a collision. To formalize the traffic rules in a precise and machine-readable manner, temporal logic languages are often used, such as Linear temporal logic (LTL) [1, 2], metric temporal logic (MTL) [3], and signal temporal logic (STL) [4].



Sketch of TC. The initially-planned trajectory for the ego vehicle violates the traffic rule starting from time-to-violation (TV) since it does not yield to vehicles entering the main carriageway from the access ramp. In our approach, the vehicle should take action before TC to avoid the incompliance.

Description

It is computationally nontrivial to ensure the compliance of real-time motion planning with all traffic rule constraints, especially in complex situations. To determine the optimal point in time at which such systems should intervene to comply with traffic rules, time-based criticality metrics such as the Time-To-Comply (TC) are proposed in [5]. The TC is the last time step for which a rule-compliant trajectory exist. Nonetheless, it is difficult to exactly compute the TC since all possible maneuvers have to be evaluated. Similar to the calculation of time-to-react in [6], [5] underapproximates the TC by introducing assessment metrics. In this thesis, we will focus on determining the point in time after which it is guaranteed that no rule-complicant maneuver exists, i.e., by using specification-compliant reachable sets [7], we overapproximate the TC, which is similar to our previous work on the worst-case analysis of the Time-To-React (TTR) [8]. The results should be demonstrated in CommonRoad[1] [9], which is a collection of composable benchmarks for motion planning on roads.

Tasks

- Literature review of works related to traffic rule formalization in [3], criticality measures, and reachability analysis [7, 10]
- Familiarizing with the current framework for underapproximating the TC and toolbox CommonRoad-Reach (reachability analysis for automated vehicles)
- Familiarizing with/Reimplementation of the existing structure of the worst-case analysis of TTR
- (optional) Implementation of worst-case analysis of TC
- (optional) Comparison with sampling-based approaches
- Evaluation of the developed approach on CommonRoad scenarios
- Integration of the approach into the CommonRoad-Repairer framework
- Documentation of codes and other related materials

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

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Research project:
-

Type:
BA/SA/GR/MA

Research area:
Motion Planning, Traffic Rules, Reachability Analysis

Programming language:
Python, C++

Required skills:
Advanced programming skill, able to work independently, familiar with motion planning algorithms

Language:
English

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

[5] Y. Lin and M. Althoff, "Rule-compliant trajectory repairing using satisfiability modulo theories," in *Proc. of the IEEE Intelligent Vehicles Symposium*, 2022.

[6] Y. Lin, S. Maierhofer, and M. Althoff, "Sampling-based trajectory repairing for autonomous vehicles," in *Proc. of the IEEE Int. Conf. on Intelligent Transportation Systems*, pp. 572–579, 2021.

[7] E. I. Liu and M. Althoff, "Computing specification-compliant reachable sets for motion planning of automated vehicles," in *2021 IEEE Intelligent Vehicles Symposium (IV)*, pp. 1037–1044, IEEE, 2021.

[8] S. Sontges, M. Koschi, and M. Althoff, "Worst-case analysis of the time-to-react using reachable sets," in *2018 IEEE Intelligent Vehicles Symposium (IV)*, pp. 1891–1897, IEEE, 2018.

[9] 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.

[10] S. Manzinger, C. Pek, and M. Althoff, "Using reachable sets for trajectory planning of automated vehicles," *IEEE Transactions on Intelligent Vehicles*, vol. 6, no. 2, pp. 232–248, 2020.

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