Velocity Planning Based Trajectory Repair for Autonomous Vehicles

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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, such as Linear temporal logic (LTL) [2], metric temporal logic (MTL) [7], and signal temporal logic (STL) [3]. However, it is computationally nontrivial to ensure the compliance of real-time motion planning with all traffic rule constraints, especially in complex situations. Obviously, if planned trajectories are not rule-compliant or physically infeasible, one can replan them for consecutive planning cycles. Nonetheless, replanning a complete trajectory is often unnecessary and time-consuming. To solve this issue, the trajectory repairing framework is proposed in previous works [5, 6].

However, existing trajectory repair methods still face computational challenges. Therefore, we address the above limitation by proposing an efficient rule-compliant trajectory repair method based on velocity planning [4]. Instead of replanning a full spatiotemporal trajectory, we reuse the original geometric path and repair the trajectory by optimizing only the velocity profile along it.

Description

The main goal of this thesis is to test the proposed velocity-planning-based trajectory repair method on our autonomous vehicle, EDGAR. You will implement a ROS 2-based software suite that integrates CommonRoad [1], our chair's open-source framework for motion planning and scenario representation, with Autoware.Universe. We do not expect applicants to already be familiar with all required tools, except Python and Ubuntu. However, we do expect a strong willingness to learn and to write code that (1) remains useful beyond a single semester and (2) can actually be used by others. The relevant tools include Ubuntu, ROS 2, RViz, Docker, and Docker Compose.

Our autonomous research vehicle EDGAR.

Tasks

- Conduct a literature review on temporal-logic-described traffic rules, and our current framework of velocity planning based trajectory repair.
- Familiarize yourself with the existing code base for trajectory repair and the software ecosystem of our autonomous vehicle, EDGAR.
- Implement and test the velocity-planning-based trajectory repair method on EDGAR in Autoware simulation.

Supervisor:
Prof. Dr.-Ing. Matthias Althoff

Advisor:
Shuaiyi Li

Research project:

Type:
MA/GR

Research area:
Safe Autonomous Driving

Programming language:
C++, Python

Required skills:
Good programming skill of C++ and Python, good knowledge of Git and Ros2 (preferrable), Self-motivated working

Language:
English

Date of submission:
Flexible

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- Further test the method on EDGAR in real-world driving scenarios.
- Document the implementation and testing results in a thesis report.

References

[1] Matthias Althoff, Markus Koschi, and Stefanie Manzinger. Commonroad: Composable benchmarks for motion planning on roads. In *2017 IEEE Intelligent Vehicles Symposium (IV)*, pages 719–726. IEEE, 2017.

[2] Klemens Esterle, Luis Gressenbuch, and Alois Knoll. Formalizing traffic rules for machine interpretability. In *2020 IEEE 3rd Connected and Automated Vehicles Symposium (CAVS)*, pages 1–7. IEEE, 2020.

[3] Luis Gressenbuch and Matthias Althoff. Predictive monitoring of traffic rules. In *2021 IEEE International Intelligent Transportation Systems Conference (ITSC)*, pages 915–922. IEEE, 2021.

[4] Kamal Kant and Steven W Zucker. Toward efficient trajectory planning: The path-velocity decomposition. *The international journal of robotics research*, 5(3):72–89, 1986.

[5] Yuanfei Lin and Matthias Althoff. Rule-compliant trajectory repairing using satisfiability modulo theories. In *2022 IEEE Intelligent Vehicles Symposium (IV)*, pages 449–456. IEEE, 2022.

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[7] Sebastian Maierhofer, Anna-Katharina Rettinger, Eva Charlotte Mayer, and Matthias Althoff. Formalization of interstate traffic rules in temporal logic. In *2020 IEEE Intelligent Vehicles Symposium (IV)*, pages 752–759. IEEE, 2020.

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