Set-based Trajectory Repair for Autonomous Vehicles

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Background

Trajectory planning is a core component of autonomous driving systems, responsible for generating feasible and safe paths that ensure collision avoidance with both static and dynamic obstacles [2]. However, due to uncertainties in the environment and unknown vehicle dynamics, planned trajectories may not always remain feasible or safe during execution. To address this challenge, various trajectory repair techniques have been proposed [1, 2, 4] to modify or adjust planned trajectories and restore safety and feasibility. Existing repair methods, however, typically operate on pointwise trajectories and assume perfect tracking without disturbances. In real-world scenarios, uncertainties and disturbances are inevitable. As a result, vehicles may deviate from their planned trajectories, and safety cannot always be guaranteed.

Description

To address these challenges, we propose a trajectory repair approach based on set-based motion primitives [3], which explicitly accounts for uncertainties by representing the ego vehicle's future states as sets rather than single points. Motion primitives are predefined behavior patterns that can be connected to form control sequences for autonomous systems. They can be precomputed and stored, enabling fast online planning for nonlinear system models.

Following [2], we first determine the cut-off state of the original trajectory to identify where the repair should begin. Subsequently, instead of generating a pointwise sequence of states, we construct a sequence of set-based motion primitives using search-based algorithms. This ensures that all possible future trajectories remain safe, regardless of disturbances and modeling uncertainties.

Tasks

- Conduct a comprehensive literature review on trajectory repair methods, motion primitives, and their applications in autonomous driving.
- Familiarize yourself with the existing code base for trajectory repair (C++, Python) and motion-primitive-based planning (Matlab).
- Design and implement the set-based motion primitive sequence generation in Matlab.
- Evaluate the performance of the proposed approach in various driving scenarios.
- Document the methodology, experimental setup, and results.

References

[1] 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.

[2] Yuanfei Lin, Sebastian Maierhofer, and Matthias Althoff. Sampling-based trajectory repairing for autonomous vehicles. In *2021 IEEE International Intelligent Transportation Systems Conference (ITSC)*, pages 572–579. IEEE, 2021.

[3] Bastian Schürmann, Daniel Heß, Jan Eilbrecht, Olaf Stursberg, Frank Köster, and Matthias Althoff. Ensuring drivability of planned motions using formal methods. In *2017 IEEE 20th International Conference on Intelligent Transportation Systems (ITSC)*, pages 1–8. IEEE, 2017.

[4] Youran Wang, Yuanfei Lin, and Matthias Althoff. Interaction-aware trajectory repair in compliance with formalized traffic rules. In *2024 IEEE 27th International Conference on Intelligent Transportation Systems (ITSC)*, pages 1850–1857. IEEE, 2024.

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Research project:

Type:
GR/SA/MA

Research area:
Autonomous Driving/Motion Planning/Safety

Programming language:
Matlab (necessary), C++ (better to have), Python (better to have)

Required skills:
Strong mathematical background (search algorithms, set-based computation); proficient in Matlab; highly self-motivated and able to work independently.

Language:
English

Date of submission:
Start as soon as possible

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