Signal Temporal Logic to Graph Search for Falsifying Autonomous Vehicles

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Background

Signal Temporal Logic (STL) is a powerful formalism used to specify and reason about temporal properties of signals in cyber-physical systems. It is widely applied in areas such as autonomous driving, robotics, and control systems to ensure that system behaviors meet desired specifications over time. Our research aims to create traffic scenarios automatically in which the vehicle under test (VUT) violates traffic rules, expressed as STL [1, 2] by steering the surrounding vehicles (aka attackers).

Description

Existing approaches require sampling complete trajectories for the attackers to evaluate the VUT's traffic rule compliance [3]. To iteratively improve the solution, optimization algorithms such as Bayesian Optimization [3] are applied. As these approaches suffer from long runtimes, you will work on a novel concept that promises to solve the task more efficiently: Instead of sampling and evaluating the attackers' trajectories as a whole, you will develop a graph search algorithm that uses motion primitives for the attackers' trajectory planning and maximizes their specification compliance.

Tasks

Your research consists of the following tasks:

- Review existing approaches for trajectory generation under STL constraints.
- Outline the functionality of your graph search approach, i.e.
- Evaluate whether additional speed-ups using heuristics and under / over approximations are possible.
- Implement your solution in Julia.
- Documentation of the code and results.

Depending on your preferences, we can adapt the task to be more theoretical or application-oriented.

References

[1] 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, 2020.

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

[3] Masaki Waga. Falsification of cyber-physical systems with robustness-guided black-box checking. In *Proceedings of the 23rd International Conference on Hybrid Systems: Computation and Control*, HSCC '20, New York, NY, USA, 2020. Association for Computing Machinery.

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Research project
Automatic testing of autonomous vehicles

Type
Master's thesis
Guided research
Semester thesis
(Bachelor's thesis)

Research area
Autonomous driving

Programming language
Julia

Required skills
Temporal logic
Work independently

Language
English

Date of submission
September 24, 2024

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