Development of a Framework for the Falsification of Autonomous Vehicles

Technical University of Munich

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Chair of Robotics, Artificial Intelligence and Real-time Systems

Please Note

This thesis proposal presents a framework. Please contact me if you are interested in working on one of its modules:

- Framework / interfaces
- Differentiable STL monitor [1, 2]
- Model predictive robustness of STL [3]
- Falsifiers / optimization [4]

Background

For the development of safe autonomous vehicles (AVs), testing against formal specifications (e.g., traffic rules) is desirable. Specifically, our research aims to falsify the vehicle under test (VUT) automatically, meaning that it violates the specifications. To this end, we express traffic rules as signal temporal logic (STL) [5, 6, 3] and steer the surrounding vehicles in a traffic scenario such that we falsify the VUT. This approach combines temporal logic with numerical optimization, with several works providing generalized solutions for the falsification [4]. To assess which falsification approach works best for our use case, we aim to have a unified framework that enables fast switching of the applied falsification strategy.

Description

You will work on a framework that is capable of monitoring the (differentiable) robustness degree of STL specifications for autonomous vehicles. Using unified interfaces, various optimization strategies can be applied to update the trajectories of the surrounding vehicles, aiming for the falsification of the VUT.

The specific tasks will depend on your topic. In general, your research will consist of the following tasks.

Tasks

- Review existing solutions for your problem at hand. What are their limitations? What would a more promising approach look like?
- Outline the functionality of your solution.
- Implement your solution.
- Documentation of the code and results.

References

[1] Shakiba Yaghoubi and Georgios Fainekos. Falsification of temporal logic requirements using gradient based local search in space and time. *IFAC-PapersOnLine*, 51(16):103–108, 2018. 6th IFAC Conference on Analysis and Design of Hybrid Systems ADHS 2018.

[2] Parv Kapoor, Kazuki Mizuta, Eunsuk Kang, and Karen Leung. STLCG++: A masking approach for differentiable signal temporal logic specification, 2025.

[3] Yuanfei Lin, Haoxuan Li, and Matthias Althoff. Model predictive robustness of signal temporal logic predicates. *IEEE Robotics and Automation Letters*, 08(12):8050 – 8057, 2023.

[4] Tanmay Khandait, Federico Formica, Paolo Arcaini, Surdeep Chotaliya, Georgios Fainekos, Abdelrahman Hekal, Atanu Kundu, Ethan Lew, Michele Loreti, Claudio Menghi, Laura

Supervisor
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Research project
Automatic testing of autonomous vehicles

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

Research area
Autonomous driving

Programming language
Python or Julia

Required skills
Temporal logic
Numerical optimization
Intrinsic motivation

Language
English

Date of submission
January 22, 2025

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Nenzi, Giulia Pedrielli, Jarkko Peltomäki, Ivan Porres, Rajarshi Ray, Valentin Soloviev, Ennio Visconti, Masaki Waga, and Zhenya Zhang. Arch-comp 2024 category report: Falsification. In Goran Frehse and Matthias Althoff, editors, *Proceedings of the 11th Int. Workshop on Applied Verification for Continuous and Hybrid Systems*, volume 103 of *EPiC Series in Computing*, pages 122–144. EasyChair, 2024.

[5] 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.

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

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