Robustness-guided Falsification of Autonomous Vehicles

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Background

For the rapid development and safety validation of autonomous vehicles (AVs), identifying the weaknesses of their motion planners is essential. For this task, various testing and validation strategies emerged. Many of these apply scenario-based testing, where the performance of AVs is evaluated in a given traffic situation. Some approaches try to force the vehicle under test (VUT) into unsafe behavior, e.g., [1]. We aim to improve these methods by employing robustness-guided falsification.

Description

With robustness-guided falsification, traffic rules (and other formal specifications) that the VUT must obey, are expressed as temporal logic. The degree of the VUT's rule satisfaction is measured using robustness metrics [2]. We control the surrounding vehicles ("attackers") such that the VUT's robustness is minimized, leading to a counter example that falsifies the motion planner of the VUT. The formulation of traffic rules as temporal logic already exists [3]. Similarly, the conversion of temporal logic into a numerical optimization problem has been shown in a minimal working example.

Tasks

The research consists of the following tasks:

- Review approaches for robustness-guided falsification techniques.
- Choose and implement a suitable falsification strategy. One possible solution:
  - Define formal scenario description.
  - Convert temporal logic (formal specification) into an automaton (using Spot[1]).
  - Create a numerical optimization problem[2] from the formal scenario description and automaton, with the robustness of the VUT as the objective.
- Combine the falsification with the CommonRoad[3] framework.
- Documentation of the code and results.

References

[1] Moritz Klischat and Matthias Althoff. Falsifying Motion Plans of Autonomous Vehicles With Abstractly Specified Traffic Scenarios. *IEEE Transactions on Intelligent Vehicles*, 8(2):1717–1730, 2023.

[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] 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.

[1] spot.lre.epita.fr
[2] gurobi.com
[3] commonroad.in.tum.de

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Research project
Automatic testing of autonomous vehicles

Type
Master's thesis
Guided research
Semester thesis

Research area
Autonomous driving

Programming language
Python
Mathematical modeling (Gurobi)

Required skills
Temporal logic
Numerical optimization
Work independently

Language
English

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