Learning Model Predictive Robustness of Probabilistic Signal Temporal Logic

Model
Predictive
Robustness

Technical University of Munich

Department of Informatics

Chair of Robotics, Artificial Intelligence and Real-time Systems

Supervisor:
Prof. Dr.-Ing. Matthias Althoff

Advisor:
Yuanfei Lin, M. Sc.

Research project:

Type:
Guided Research/Master Thesis

Research area:
Motion Planning, Temporal Logic, Traffic Rules, Machine learning

Programming language:
Python

Required skills:
Advanced programming skill, able to work independently, familiar with machine learning approaches

Language:
English

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For more information please contact us:

Phone: -

E-Mail: yuanfei.lin@tum.de

Website:
www.ce.cit.tum.de/air/people/yuanfei-lin-msc/

Background

Formal methods have been crucial for cyber-physical systems to verify safety, formalize task specifications, and synthesize trajectories [1, 2, 3]. Temporal logic, such as linear temporal logic (LTL) [4], metric temporal logic (MTL) [5], and signal temporal logic (STL) [6], allows specifying unambiguous requirements, e.g., traffic rules for autonomous vehicles, due to their rich expressiveness. MTL and STL are equipped with quantitative semantics, i.e., the robustness degree (aka robustness) [7, 8], which measures the degree of satisfaction or violation of a system with respect to the given specification.

For uncertain and changing environments, a probabilistic variant of STL is proposed to express safety constraints on random variables and stochastic signals in [9, 10, 11]. Similarly, Lee *et. al.* [12] extend STL with random predicates to formulate a controller synthesis problem as probabilistic inference.

Description

The original robustness degree for probabilistic STL predicates is defined in a model-free way, i.e., without considering the underlying system dynamics. Therefore, it does not embody or predict the real capability of the system to meet the specifications and is not scalable for complicated predicates. In our previous work, we have proposed a model predictive robustness (MPR) for original STL predicate [8], which is defined as a probability distribution anticipating future changes in specification satisfaction or violation. Therefore, to address the above mentioned issues, MPR needs to be included to probabilistic STL and applied to motion planning and control problems. Moreover, the results should be demonstrated in CommonRoad[1] [13], which is a collection of composable benchmarks for motion planning on roads.

Tasks

- Literature review of works related to stochastic model predictive control as well as temporal logic and its probabilistic variants.
- Familiarizing with the current MPR definition and the existing traffic rule monitor in CommonRoad platform
- Learning the MPR for probabilistic STL formulae and testing the new definition in benchmark specifications, e.g., from stlpy[2] [14]
- Extending the approach to motion planning problems for autonomous vehicles and evaluating the developed approach on CommonRoad scenarios
- Documentation of codes and other related materials

[1] https://commonroad.in.tum.de/
[2] https://github.com/vincekurtz/stlpy

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