Errors of Trajectories for Autonomous Vehicles and Cyber-Physical Systems

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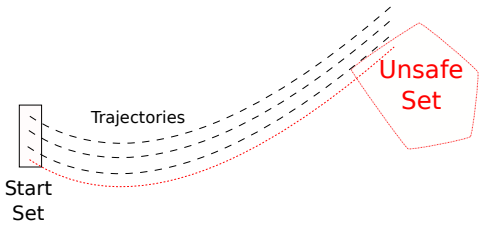
Background

The application of cyber-physical systems in safety-critical environments requires formal verification techniques in order to ensure correct functionality. Reachability analysis is one of the main techniques to provide safety guarantees: The key idea is to compute all possible states that the system can reach after a given time, and then check whether any of these states intersects with a dangerous object. If no reachable state is dangerous, then safety has been formally verified.



A common strategy to compute the set of reachable states is to first compute an approximation of all possible trajectories, and then add an error term that depends on the worst-case error of said approximation. This takes the form of an error set that has to be added to each trajectory. Since this process may have to be used for several time steps, the error set can become very complex, and may need to be overapproximated using a simpler set (this is called order reduction). The performance of an algorithm is directly tied to how good or bad this overapproximation is chosen. Recently, the error of such overapproximations could be determined for the simple case of an interval-box overapproximation [2]. It is therefore of interest whether such an approach could be extended to other overapproximations.

Description

The goal of this thesis is to generalize the approach given in [2]. Specifically, the idea is to use PCA-reduction [1] instead of box-reduction. The error of such a reduction will have to be estimated, and the resulting improvements should be tested on several models for autonomous vehicles and robots.

All programming will be done in Matlab, and the final implementation of the approaches should be integrated into the CORA toolbox so that it can be made publicly available in the next CORA release.

Tasks

- Literature review on the topic of reachability analysis and order reductions
- Estimation of the error produced by a PCA-reduction
- Evaluation of the performance by comparing the result to the currently implemented method in CORA
- Integration of the final implementation into the CORA toolbox

References

[1] Anna-Kathrin Kopetzki, Bastian Schürmann, and Matthias Althoff. Methods for order reduction of zonotopes. In *2017 IEEE 56th Annual Conference on Decision and Control (CDC)*, pages 5626–5633, December 2017.

[2] Mark Wetzlinger, Adrian Kulmburg, and Matthias Althoff. *Adaptive parameter tuning for reachability analysis of nonlinear systems*. May 2021. Pages: 11.

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Research project:
justITSELF

Type:
Master Thesis

Research area:
Reachability Analysis

Programming language:
MATLAB

Required skills:
Good mathematical background, in particular linear algebra and calculus.

Language:
English

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