Improving Novel Control Methods with Safety Guarantees for Disturbed Nonlinear Systems

Background

Many modern control scenarios require the control of complex, nonlinear systems acting in safety critical environments, such as autonomous cars or for robots interacting with humans. Thereby, formal guarantees for the satisfaction of hard input and state constraints are necessary despite the influence of disturbances. Hardly any efficient control methods exist which can take all of these requirements into account. Instead, it is often the case that a controller is developed for the nominal case and afterwards it is tested if it satisfies the constraints. Clearly testing is never enough, since only finitely many test cases can be considered. These guarantees can only be obtained by using formal verification methods, such as reachability analysis for dynamical systems. This means that after developing classical controllers, one tries to verify it. If this fails, a new controller is designed and verification is tried again. This can easily lead to many iterations.

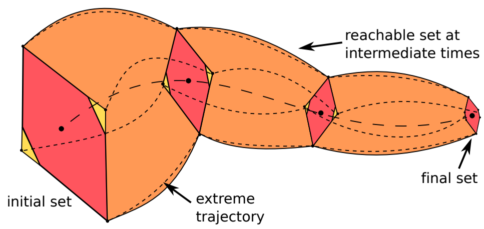

Illustration of novel, set-based control approach from [1], where a formal control law for a set of initial states is obtained by interpolating the optimal solutions for single extreme states.

In order to overcome the described difficulties, we recently proposed new ways of designing controllers by including the formal verification techniques already inside the controller design process [1, 2]. This allows us to directly optimize the control performance while taking constraints and disturbance effects into account, even for nonlinear systems. Since the formal guarantees are obtained using reachability analysis, there is no need to find Lyapunov functions or use similar techniques. Instead, the goal is to obtain "push-button" approaches, which are simple to use. Moreover, the complexity of the developed methods is much better than most existing controller design approaches which provide formal guarantees.

Tasks

The goal of this thesis is to improve and further develop one of these control approaches. As this is a new way of viewing control, there exist many interesting possibilities how the performance and the applicability of these methods can further be improved. One way is by obtaining heuristics based on simplified models which are then used to obtain formal controllers for more complex models. Another improvement is to combine the new optimization based controller design approaches from [2] with more complex, existing control methods in order to obtain an improved control performance with formal guarantees.

Therefore, if you have a strong background in control theory and in dynamical systems, this thesis offers the chance to work on a completely new, state-of-the-art control method, which offers many advantages over other control approaches. The methodical topic with practical motivation offers the possibility to learn more about control, optimization, and formal verification and to work on an interesting open research question.

References

[1] Bastian Schürmann and Matthias Althoff. Convex interpolation control with formal guarantees for disturbed and constrained nonlinear systems. In *Proc. Hybrid Systems: Computation and Control*, 2017.

[2] Bastian Schürmann and Matthias Althoff. Optimal control of sets of solutions to formally guarantee constraints of disturbed linear systems. In *Proc. of the American Control Conference*, 2017.

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