Ensuring Safety for Autonomous Systems

Background

In safety-critical applications, e.g., control of autonomous robots (drones, cars) or human-robot-collaboration, it is crucial to guarantee safety for an infinite time horizon. This can be achieved by using invariant sets as terminal sets, i.e., the state of the dynamical system is controlled from an initial point into an invariant set $S$ [1, Ch. 4]. After entering $S$, it is known that the state trajectory will never leave $S$ again. If $S$ is a safe set, i.e., all constraints are fulfilled, then safety of the autonomous system can be guaranteed for an infinite time horizon.

However, widely used polytopic methods to compute invariant sets have a high computational complexity with respect to the state space dimension of the system. In contrast, our reachability analysis is based on zonotopes and scales only polynomially [2]. Recently, it has been used to compute invariant sets for discrete-time systems [3].

Description

The aim of this thesis is to extend the approach in [3] to continuous-time systems that are controlled by discrete-time digital controllers. This class of systems is also known as sampled-data systems [4], i.e., the state measurements and the control signals are only updated at discrete time steps, while the safety of the autonomous system must be guaranteed also between two sampling instants. We intend to include the results of this thesis in an international publication.

Tasks

- Familiarizing with invariant sets for infinite and finite time horizons
- Familiarizing with reachability analysis
- Implementing and integrating the sampled-data invariant set approach into our open-source MATLAB tool CORA [5]
- Comparing the performance with other methods based on polytopes and ellipsoids

References