Fast Low-Dimensional Projections of High Dimensional Nonconvex Polytopes

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Internship Description

The SpaceEx verification platform is a state-of-the art model checker for a variety of systems involving real-valued variables that change continuously over time [2]. This includes a wide range of embedded systems, control systems, biological systems, electric circuits etc. Part of the model checking process is the approximation of dense families of continuous trajectories, i.e., the evolution of the continuous variables over time. A recently developed technique computes a nonconvex polytope that covers all trajectories [1]. The construction is highly efficient and can be applied to systems with hundreds of variables, which is orders of magnitude above classical methods.

The goal of this project is to develop a methodology to compute projections of these nonconvex polytope into 2D/3D space, for visualization and further processing. This projection is computationally infeasible using classical methods (quantifier elimination). One possible approach is to extend polytopic sandwich approximations, known for convex sets, to nonconvex polytopes. The approach can exploit the fact that the nonconvex polytopes are pointwise convex in the dimension that represents time.

The SpaceEx core consists of +100k lines of C++. It is complemented by a model editor and a graphical user interface written in Java. The projection engine, created in the course of this project in either C++ or Java, should be capable of computing and visualizing 2D/3D projections of high-dimensional nonconvex polytopes in a reactive and interactive manner.

Requirements Candidates should have solid knowledge of Java or C++. Knowledge of linear programming, convex bodies and hybrid systems is a plus, but not required.

Keywords Polytopes, Convex Sets, Hybrid Systems, Projection

References

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[2] G. Frehse, C. Le Guernic, A. Donzé, S. Cotton, R. Ray, O. Lebeltel, R. Ripado, A. Girard, T. Dang, and O. Maler. SpaceEx: Scalable verification of hybrid systems. In G. Gopalakrishnan and S. Qadeer, editors, *CAV*, volume 6806 of *LNCS*, pages 379–395. Springer, 2011.