



Symbolic and Numerical Techniques for Verification and Synthesis of CPS

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Goal: Develop Scalable Controller Verification and Synthesis Techniques.

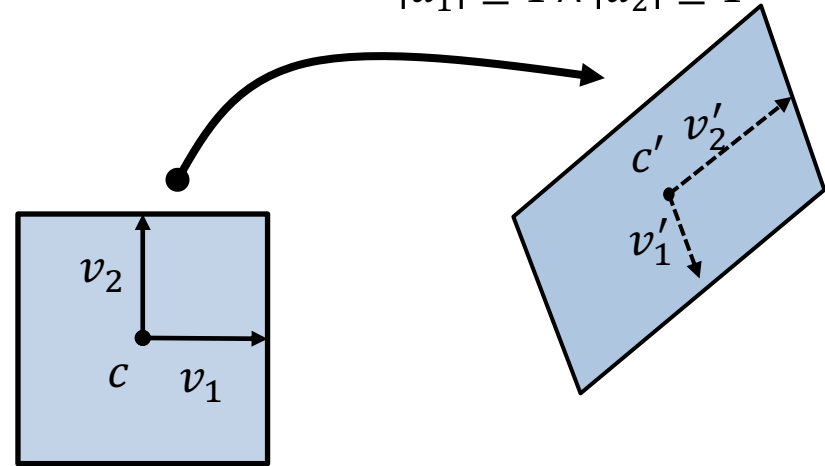
Develop a combination of symbolic and numerical techniques for achieving the goal.

Goals of This Project :

- Enhance *generalized stars*, a symbolic representation that is very efficient for computing reachable set for linear systems.
- Develop new mechanisms for generating counterexamples for safety specification.
- Develop safe-by-construction linear control systems by integrating counterexamples in controller synthesis.

$$\text{Reach}(\Theta, t) \triangleq \langle c', V', P \rangle$$

$$|\alpha_1| \leq 1 \wedge |\alpha_2| \leq 1$$



$$\Theta \triangleq \langle c, V, P \rangle$$

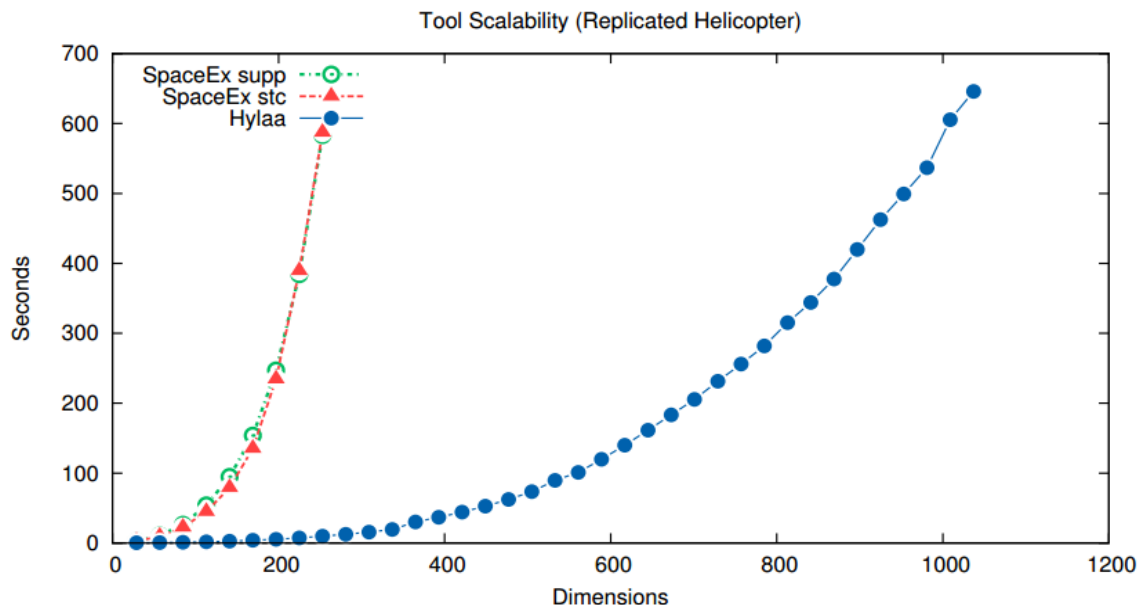
$$|\alpha_1| \leq 1 \wedge |\alpha_2| \leq 1$$

Why generalized stars?

- 1) Because linear transformation, Minkowski sum, and intersection can be performed very efficiently.
- 2) Improved the scalability of verification by two orders of magnitude.

Research Results

- Developed new techniques for overapproximating union of stars.
- Developed new techniques for generating *longest* and *deepest* counterexamples.
- Embedding trajectories into a low dimensional space for understanding structure better.
- Extended generalized stars to handle modeling errors using bilinear inequalities.



# Dims	supp	stc	HyLAA
29	2.98	2.60	0.42
57	10.93	9.48	0.67
141	94.83	79.23	2.65
253	583.27	587.42	9.79
449	-	-	52.67
1009	-	-	605.38

<https://github.com/stanleybak/hylaa>

Education and Mentorship

Mentorship:

- One graduate student (Bineet Ghosh) and two undergraduate students (Jonathan Homburg and Nandan Tumu) mentored.
- Resulted in one undergraduate honors thesis: Jonathan Homburg.
- Nandan represented UConn in F1Tenth events. Correctness by construction of autonomous vehicle controllers.
- Capstone project on formally specifying properties of elevator systems.

Teaching:

- Teaching formal methods course for practicing engineers.
- Introduction to control design and model checking.