HyRG: A Random Generation Tool for Affine Hybrid Automata

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Abstract

HyRG: Hybrid Random Generator prototype tool

- Randomly generating hybrid automata with affine differential equations, invariants, guards, and updates
- Partition the set of all affine functions into potentially interesting classes and randomly select random elements from these classes
- Partition the components describing discrete behavior (guards, updates, and invariants) to generate either time-dependent or state-dependent switching system
- Provide the ability to generate subclasses of piecewise affine hybrid automata

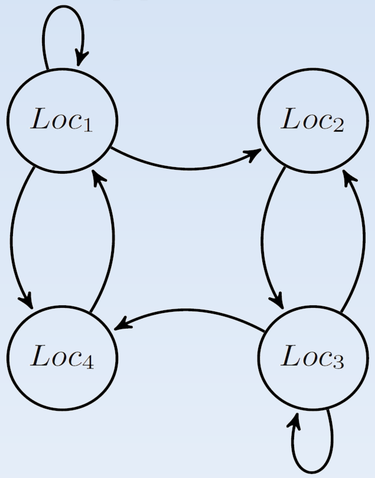
Objectives

Our work on random generation of hybrid automata is essential for

- Evaluating reachability algorithms
- Testing various components (from parsers to analysis algorithms) in analysis tools
- Testing translators from hybrid systems modeling languages to other tools like Mathworks Simulink/Stateflow
- Developing libraries of examples with diverse continuous and discrete behaviors.

Discrete Structure

The discrete structure of a hybrid automata can be randomly generated using random adjacency matrices [1]



$$A_G = \begin{pmatrix} 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

An example of the transition graph of the hybrid automaton randomly generated by the random adjacency matrix A_G

Continuous Flow Dynamics

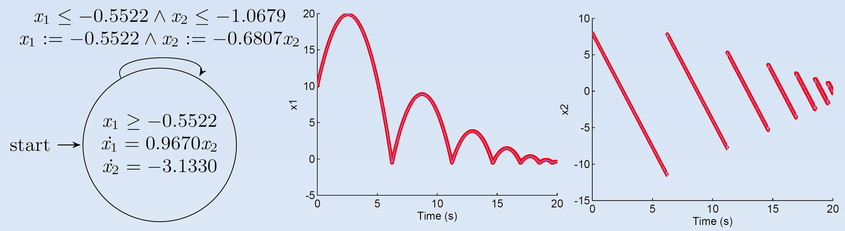
For linear systems, the continuous dynamics has a general solution

- Randomly generate a matrix of eigenvectors as an arbitrarily non-singular $n \times n$-matrix,
- Add constraints over the randomly generated $n \times n$ diagonal matrix of eigenvalues $\boldsymbol{D}$.
- $\boldsymbol{C}$ is an n-vector of real values determined by the arbitrary initial conditions of

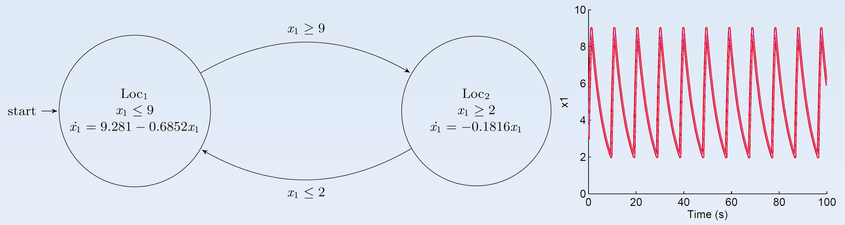
HyRG can randomly generate many classes of continuous dynamics with different stability scenarios based on manipulating different sets of given eigenvalues [2]

Experimental Results

We implemented the prototype HyRG tool in Java and Matlab and evaluated it in several scenarios



A hybrid automaton randomly generated by HyRG with similar behavior to the bouncing ball (BB) example



A hybrid automaton randomly generated by HyRG with similar behavior to the thermostat/heater example

Example		Mean	Median	Std.Dev	Min	Max
BB	N	111.63	65	120.26	1	661
	T	17.022	9.824	18.615	0.0946	101.23
Heater	N	2126.5	1481	2152.2	24	10710
	T	216.35	152.13	219.15	2.4855	1091.5

HyRG trial table for randomly generating 100 bouncing ball and thermostat/heater examples

References

[1] Godsil, C., Royle, G.: Algebraic graph theory, volume 207 of Graduate Texts in Mathematics. Springer-Verlag, New York (2001)

[2] M. Althoff, B. H. Krogh, and O. Stursberg. Analyzing reachability of linear dynamic systems with parametric uncertainties. In A. Rauh and E. Auer, editors, *Modeling, Design, and Simulation of Systems with Uncertainties*, volume 3 of Mathematic