Bisimulations for polynomial differential equations

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Abstract

Ordinary differential equations (ODEs) with polynomial derivatives are a fundamental tool for understanding the dynamics of systems across many branches of science, but our ability to gain mechanistic insight and effectively conduct numerical evaluations is critically hindered when dealing with large models. In this talk I will present an aggregation technique that rests on two notions of equivalence relating ODE variables whenever they have the same solution (backward criterion) or if a self-consistent system can be written for describing the evolution of sums of variables in the same equivalence class (forward criterion). A key feature is the encoding of a polynomial ODE system into a finitary structure akin to a formal chemical reaction network. This enables the development of a partition-refinement algorithm to efficiently compute the largest equivalence, building on approaches rooted in probabilistic bisimulation. I will discuss the physical interpretability of the aggregation in applications to biochemical reaction networks, gene regulatory networks, and evolutionary game theory.