Developing a computationally efficient algebraic/combinatorial framework for nonlinear dynamics

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Typical descriptions of the behavior of nonlinear dynamical systems focus on invariant sets. This leads to an amazingly rich mathematical theory, both in terms of the variety of invariants and the variety of bifurcations between different invariant sets. This richness leads to problems in the context of multiscale applications where one does not have exact models, i.e. the nonlinearities are not known from first principles, or equivalently parameters are unknown or at best poorly known, and in settings in which only crude measurements of the system can be made.
With this in mind I will describe our efforts to develop a computationally efficient, but mathematically rigorous framework for extracting combinatorial/algebraic topological descriptions of the global dynamical structures of multi-parameter nonlinear systems.