Towards a Computational, Discrete Geometric Foundation for Nonlinear Dynamics

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Abstract The current paradigm for nonlinear dynamics focuses on the existence and structure of invariant sets. As over a century of work shows this is an incredibly rich subject and perhaps, from the perspective of modern applications, too rich. For example, in general, invariant sets are not computable and structurally stable systems are not generic. As consequence it appears difficult to develop a natural methodology for analyzing dynamics in the context of scientific challenges driven by data as opposed to mathematical models.

In this talk I will describe an alternative approach to dynamics based on using order structures to identify gradient versus recurrent-like behavior and algebraic topology to characterize local and global structures of the dynamics. Using regulatory networks arising from systems biology as motivation I will demonstrate some advantages of this approach: it allows for finite queryable descriptions of global dynamics; it leads to natural decompositions of parameter space; it lends itself to efficient computations; and the results lead to mathematically rigorous statements about the possible dynamics of more traditional models based on differential equations.

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