Structure based dimension reduction in network dynamical systems

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Many dynamical systems in fields such as neuroscience (the workings of the brain), systems biology (metabolic networks), and robotics (robot swarms) exhibit the structure of a network: they consist of nodes (neurons, proteins, robots) interconnected by edges. The specific architecture of these interactions can give rise to remarkably complex dynamics that go far beyond the behavior of individual nodes. Prominent examples include synchronization and intricate branching patterns in bifurcations—phenomena that do not arise in general dynamical systems lacking a network structure.

In this talk, I will explain how structural features of a network give rise to (non-classical) symmetries in the governing equations. These symmetries encode the intrinsic structure of the network and can be exploited to uncover model-independent dynamical features—geometrical or topological properties of solutions that are solely determined by the interaction structure, regardless of the specific form of the equations. In the second part, I will demonstrate how these symmetries can be systematically analyzed to achieve dimension reduction in bifurcation problems. This reduction enables a tractable, model-independent characterization of the generic bifurcation behavior associated with a given network structure—providing a powerful framework for understanding the emergence of complexity in networked dynamical systems.