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Boolean vs. ODE models of gene regulatory and other systems

Many biological networks exhibit switch-like behavior. Examples include gene regulatory networks and neuronal networks. Boolean and other discrete dynamical systems with a finite state space appear to provide natural frameworks for modeling such systems. The dynamics of these models are often easier to study than the dynamics of ODE systems that incorporate more biologically realistic details, and the former models can be considered coarse-grained approximations of the latter. The question arises, however, under which conditions the dynamics of the Boolean approximations reliably reflect the dynamics of the underlying ODE systems.

In this talk we will define precise notions of correspondence between an ODE system and its Boolean approximations and review some results from the literature that prove correspondences for certain systems. Examples include models of gene regulation, neuronal networks, and classes of toy models that allow elucidation of some important mechanisms. This brief review will show some commonalities and differences between the results for the various classes of models.

We will then present some results on how these differences can be explained. Our particular focus will be the role of separation of time scales. While the results on neuronal networks and certain toy models hold as long as the separation of time scales is sufficiently large, the correspondence is lost in models of gene regulatory networks when the separation increases beyond a certain value. We will discuss which features of the underlying ODE's may explain this phenomenon.