Truth-content and phase transitions of random boolean networks with generic logics

One distinguishes between qualitative and Boolean models of gene regulatory networks. Qualitative models are directed graphs with signed edges according to whether an interaction is activating or inhibiting. In Boolean models each node of the network is a Boolean variable whose value depends on the values of the node’s regulators according to a specific update rule. Qualitative models can be systematically converted into Boolean models via generic logics, which allow combination of activating and inhibiting influences into an update rule. Here, we investigate random Boolean networks whose update rules are generated using generic logics. We begin by studying their truth-content, which is a mean field approximation of the fraction of ones (true nodes). We prove that the asymptotic behavior of this quantity is essentially independent of the initial conditions. In numeric analyses, the truth-content exhibits a rich dynamical behavior including period-doublings leading to chaos. We define truth-stable networks as networks whose truth-contents exhibit non-chaotic dynamics. Random Boolean networks are known to exist in two phases: a frozen phase with stable short periodic dynamics and a chaotic phase characterized by long-periodic attractors sensitive to perturbations. Our results about the truth-content of random Boolean networks with generic logics allow us to derive a criterion for phase transitions in these networks. The relation between phase transitions and the concept of truth-stability is
studied. In numeric analyses we find multiple, intricately shaped critical boundaries. Simulations further strengthen the significance of our mean field results. Our results nicely fit into the theory of 'living at the edge of chaos,' which aims at elucidating the crucial properties of evolvable biological systems.

Stichworte: gene regulatory network time-discrete system mean field approximation S-unimodal map


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