QUANTIFYING STABILITY IN DETERMINISTIC AND STOCHASTIC COMPLEX NETWORKS AND ITS APPLICATION TO POWER GRIDS

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Abstract: Power grids, the human brain, arrays of coupled lasers, genetic networks, or the Amazon rainforest are all characterized by multistability. The likelihood that these systems will remain in the most desirable of their many stable states depends on their stability against significant perturbations, particularly in a state space populated by undesirable states. Here we claim that the traditional linearization-based approach to stability is in several cases too local to adequately assess how stable a state is. Instead, we quantify it in terms of *basin stability*, a new measure related to the volume of the basin of attraction. Basin stability is non-local, nonlinear and easily applicable, even to high-dimensional systems. It provides a long-sought-after explanation for the surprisingly regular topologies of neural networks and power grids, which have eluded theoretical description based solely on linear stability.

Further, we analyse the particular function of certain network motifs to promote the stability of the system. Here we uncover the impact of so-called detour motifs or loops on the appearance of nodes with a poor stability score and discuss the implications for stability. Remarkably, when taking physical losses in the network into account, the back-reaction of the network induces new *exotic solitary states* in the individual actors, and the stability characteristics of the synchronous state are dramatically altered. These novel effects will have to be explicitly taken into account in the design of future power grids, and their existence poses a challenge for control.

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