A study of the dynamic range of an Ising model with delayed interactions under self-organization

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The Ising model is used to study the development of associative memories in neural networks, such that spins represent two-state neurons (active, or spiking, and inactive, or silent). The Ising model is also a standard model for the critical point in second order equilibrium phase transitions and has been employed to describe experimental findings in brain recordings, such as neuronal avalanches [1], pairwise correlations [2] and the entropy of cortical states. Moreover, a procedure to self-organize the Ising model towards the critical point has been proposed via Monte Carlo simulations [3]. The dynamic range is the interval of temporal input stimuli that causes a sensible variation in the macroscopic response of the system, and is an important property of sensory systems in the brain. The critical point of models in the directed percolation universality class was shown to maximize the dynamic range of the network. In order to study the temporal input sensitivity of magnetic models, we reinterpret the ANNNI (Axial Next-Nearest Neighbor Ising) recurrent equation in the Bethe network as a Glauber-like non-Markovian dynamics where iterating over the Bethe network layers corresponds to iterating over Monte Carlo time steps. We then measure the magnetization response to an applied magnetic field and show that the dynamic range of this system is maximized throughout the critical line, including at the Lifshitz point. Finally, we propose a mean-field version of the Chialvo self-organizing dynamics for the Glauber-ANNNI model and characterize its influence on the dynamic range of the system.

References

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