A Coevolutionary Model with Self-Organized Criticality for Neural Networks with Different Diversities

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It is believed that neural networks in the brain work at, or near, the state of self-organized criticality (SOC). Inspired by the recent progress of experiments in neuroscience, we propose a generalized version of SOC model for neural networks by Arcangelis *et al.* with some new ingredients introduced. Starting from regular two-dimensional (2D) square electric lattice of the original model, we add long-range connections between neurons with the probability p_{ij} ~ *r^\delta_ij* to form a small-world (SW) network, where r_{ij} is the geometric distance between any pair of sites *i* and *j*, and *\delta* is a constant exponent under the constraint of certain total cost (length) for these connections. Neuronal diversity is introduced by considering a random distribution of firing thresholds. Updating rule of synaptic conductance is modified to avoid frequent cutting-off of synapses in the previous model. Furthermore, the effect of slow process of synapse rewiring is tested by assuming another random distribution of periods. Numerical simulations show that three diversities–in topology, neuronal thresholds and synaptic rewiring time scales–give positive contributions in generating SOC characterized by the power-law distribution of avalanche sizes of neural firings in such co-evolutionary networks, with the exponent *\tao* ~1.5 corresponding to medical measurements. The present work implies that SOC may be robust to randomness existing in nervous processes.

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