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Designing Smooth Energy Landscapes using Coherent Collective Interactions

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I propose how to design smooth energy landscapes in frustrated Ising models. Starting from the well-known Hopfield model, I discuss how frustration gives rise to many local minima on its energy surface. I then look at many-body generalizations of the two-body Hopfield Hamiltonian, and how their energy landscapes are even more rugged.

I propose another way to generalize many-body interaction such that the energy landscape becomes smoother instead of rougher. The main idea is that a collection of k-spins will produce a force only if they are completely aligned (i.e. coherent) with the exchange interaction. This is in stark contrast to traditional many-body Hamiltonians (i.e. $-\sum J_{i\cdots k} x_i \cdots x_k$) where higher-order spin groups $x_i \cdots x_k$ interact via direct product. Why frustration is reduced is explained. I call this the Coherent Spin-Interaction (CSI) model.

In numercial calculations, the CSI model is studied using two approaches. In the first approach, changes in the energy landscape structure is studied by monitoring the attractors, repellers, and quasi-separatrices as the number of spins k in a group increases. In the second approach, order parameters are defined and phase transitions of the model is studied with respect to three variables: k, α (loading parameter), and T (temperature). From both studies, it is found that coherent many-body interaction smooths the rough energy landscape of the two-bodied Hopfield model.

[1] Y. W. Koh and K. Takatsuka, Neural Computation, Vol 21 Issue 5 , May 2009, pp. 1321-1334.