Spin glass algorithms to control the training of energy-based generative models

Beatriz Seoane[1]

[1]Universidad Complutense Madrid, Madrid, Spain

Energy-based generative models, such as Restricted Boltzmann Machines (RBMs), can be viewed as disordered spin systems that explicitly parametrize high-dimensional probability distributions. This perspective enables the direct application of methods from spin glass theory to analyze and control their training dynamics. Despite their conceptual appeal, however, these models remain challenging to train and to sample from efficiently.

In this talk, I will show that training instabilities originate from inaccurate Monte Carlo estimates of the gradient, which hinder proper equilibration of the underlying spin-glass system during learning. A physical analysis of the evolving free-energy landscape along the training trajectory reveals the core mechanism: the progressive crossing of multiple second-order phase transitions, accompanied by the emergence of an increasingly complex structure in the model.

Building on this perspective, I will present spin-glass-inspired algorithms that restore control over the sampling dynamics, enabling fast and accurate training. These results position RBMs and related energy-based models as inference tools whose behavior can be systematically understood within the framework of disordered systems.