Machine Learning Nonequilibrium Phase Transitions

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We present an investigation of a convolutional neural network (CNN) prediction that successfully recognizes the critical temperature of nonequilibrium phase transitions in 2D Ising spins on a square lattice. The model uses image snapshots of ferromagnetic 2D spin configurations as the `input_shape` to provide the average output predictions. By considering supervised machine learning techniques, we perform Metropolis Monte Carlo (MC) simulations to generate the configurations. In the equilibrium Ising model, the Metropolis algorithm respects the detailed balance condition (DBC), whereas its nonequilibrium version violates DBC. Violating the DBC of the algorithm is incorporated through a parameter $-8 < \varepsilon < 8$. Analytically we find a graphical solution of the critical temperature. A setup with $\varepsilon = 0$ restores the usual Metropolis algorithm which helps to generate the equilibrium configurations (`train_dataset`). For a nonzero ε, the system attains nonequilibrium steady states (NESS), and the modified algorithm generates NESS configurations (`test_dataset`). After training the model on the `train_dataset`, it has been tested using the `test_dataset`. The result shows that CNN can determine the transition temperature for various $-4 \leq \varepsilon \leq 8$., which is consistent with both MC and graphical results. The discrepancy for $-8 \leq \varepsilon \leq -4$ is main due to the fact that quantum fluctuation is more pronounced at low temperature, Reference [1].

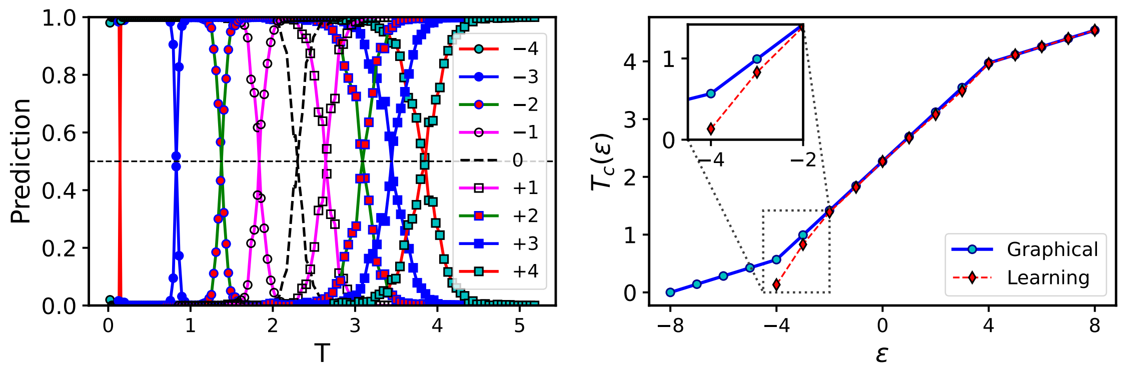

Figure 1: Plot of T_c vs ε, identifying critical temperature dependence on nonequilibrium parameter.

[1] DW. Tola, M. Bekele, Condens. Matter **8**, 83 (2023).