Kinetic constraint-induced thermodynamic phase transitions in lattice spin models

Hai-Jun Zhou[1]
[1]*Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing*

The Fredrickson-Andersen (FA) model with hyperparameter K = 1 is a severely constrained kinetic lattice spin system, such that any site is temporarily blocked from changing its packing state (empty or occupied) if there is one or more occupied nearest neighbors. Starting from a completely random initial configuration with a fraction rho of sites being occupied, some of the sites may be permanently frozen to their initial state under this severe kinetic constraint. The remaining sites can switch states at least occasionally, and they form the unfrozen subsystem associated with the given initial configuration. The FA model is one of the basic models for understanding glassy dynamics [1].

In the present work we investigate thermodynamic phase transitions in such unfrozen subsystems of the two-dimensional square lattice and the three-dimensional cubic lattice by extensive numerical simulations [2]. We demonstrate that the giant connected component of the unfrozen subsystem will collapse at certain critical value rho_c of initial packing density, with rho_c = 0.2475 for the square lattice and rho_c = 0.2809 for the cubic lattice. This phase transition belongs to the same universality class of the conventional site percolation transition. We also observe that the ground states (densest packing configurations) experience a continuous crystal-to-glass phase transition at the critical value rho* = 0.1429 of initial packing density for the cubic lattice. For the two-dimensional square lattice we argue that long-range crystalline order is destroyed in the ground states as long as the initial packing density rho is positive.

We also extend this work to the case of K = 2, in which any site is temporarily blocked from changing its packing state if there are two or more occupied nearest neighbors. We also observe continuous phase transitions in three-dimensional cubic lattice.

[1] Hai-Jun Zhou, Chinese Physics B 33, 066402 (2024).

[2] Ruifeng Liu, Jianwen Zhou, Yejia Chen, Jiahang Chen, and Hai-Jun Zhou, Physical Review E (2026) under review.