PARALLEL HYBRID MULTISPIN MONTE-CARLO METHOD FOR THE EDWARDS-ANDERSON SPIN GLASS MODEL

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Introduction

During the 1960s, it was revealed that some magnetic alloys have unusual magnetic properties. This discovery led to the development of spin glass models, which are used to study complex disordered systems. Spin glasses are characterized by two main characteristics that strongly distinguish these systems from others: disorder in the position of magnetic atoms in the alloy and the occurrence of strong competition between ferromagnetic and antiferromagnetic interactions.

Model

In this paper, the authors consider the two-dimensional Edwards-Anderson model [1], with the exchange integral J_{ij} as a random function and the average value of J_{ij} is zero. In such a system, at one-half of the spins the interaction with each other is ferromagnetic, and at the other - antiferromagnetic. The interaction J_{ij} between the spin pair (ij) changes during the transition from one pair to another. The Hamiltonian is expressed as:

$$H = -\sum_{<i,j>} J_{ij} S_i S_j - h \sum_{i=1}^{N} S_i$$

S_i, S_j – spins of the lattice, $<i,j>$ denotes the summation over pairs of interacting spins in a system with size N, h is the external magnetic field.

Results and discussions

One of the actual problems for the Edwards-Anderson model is the search for the ground state. We proposed parallel modification for multispin Monte Carlo algorithm. [2]. To speed up the calculations it was proposed to use parallel computing using the OpenMP library. The number of clusters should be equal to the number of threads. Our method allows one to search for low-energy states or even ground states. We are based on the assumption that minimization of the energy of subsystems should lead to the minimization of the energy of the whole system.

We calculated ground states of considered model with lattice size of 36, 100, 400 and 900 spins using various methods (Table 1). The proposed method showed efficiency at the level of exact solution at small lattice sizes, and the lowest ground state value at large lattices, remaining the calculation speed on Monte Carlo level.

Table I. Comparison of the values of the main states of the system obtained by different methods

Lattice size	Exact solution	Replica-exhange Monte Carlo	Hybrid Monte Carlo	Parallel hybrid Monte Carlo
6x6	-1.50	-1.27	-1.33	-1.50
10x10	-1.40	-1.24	-1.32	-1.40
20x20	-	-0.98	-1.06	-1.34
30x30	-	-0.76	-0.79	-1.34

Conclusion

In this work, we have demonstrated that the parallel hybrid MC method showed greater efficiency, then various variations of regular Monte Carlo methods.

[1] S. Edwards, P. Anderson, Theory of spin glasses, Journal of Physics F: Metal Physics 5 (5) (1975) 965–974 [2] K. V. Makarova, A. G. Makarov, M. A. Padalko, V. S. Strongin, K. V. Nefedev, “Multispin Monte Carlo Method”, Dal'nevost. Mat. Zh., 20:2 (2020), 212–220