A Method to Control Order of Phase Transition: Invisible States in Discrete Spin Models

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Quantum annealing method (a kind of quantum adiabatic computation) was proposed in terms of statistical physics as an alternating method of simulated annealing. This is a general-purpose algorithm for optimization problems and expected an efficient method. Quantum annealing method does not succeed to obtain the optimum solution of the systems exhibiting the first-order phase transition because of the existence of hysteresis at the first-order phase transition point.

Thus, it is an important issue to develop a method to control the order of phase transition without changing the ground state. If possible it is best to erase the phase transition. The simplest way to control the order of phase transition is to add an extra degree of freedom. To consider this situation for simplicity, we invent the ferromagnetic Potts model with invisible states that are added as an extra degree of freedom [1-4]. Invisible states are introduced to affect the entropy and the free energy, although they do not contribute to the internal energy. Thus, properties of the ground state do not change by adding invisible states. In this study, we consider the nature of phase transition in the Potts model with invisible states by mean-field calculation and Monte Carlo simulation. A second-order phase transition takes place at finite temperature in the standard q-state ferromagnetic Potts model on the two-dimensional lattice for q = 2, 3, and 4. However, our introduced model on the two-dimensional lattice undergoes a first-order phase transition with spontaneous q-fold symmetry breaking (q = 2, 3, and 4) due to the entropy effect of invisible states. We propose a method to change the order of phase transition without changing properties of the ground states.

Unfortunately, invisible states stimulate the first-order phase transition. However, our method to introduce new degree of freedom into discrete spin models is general and the invisible state is just an example. We believe that a useful degree of freedom for quantum annealing can be made up by our general method.

References

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