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Unusual changeover in the transition nature of local-interaction Potts models

Abstract

The ferromagnetic q-state Potts model describes a classical spin system, defined on some lattice and, in general, governed by the simple following interaction rule. Each spin possesses one out of (integer) q possible states. If the interacting spins are monochromatic (have the same state) the energy of the system is lower than the case where they hold different states. Although the model has been extensively studied in the past few decades and the amount of literature revealing various interesting related phenomena is enormous, a particular phenomenon that has been sparsely investigated is the changeover from a second to a first order phase transition at a critical integer value q_c, or, in short, the changeover phenomenon. A long-standing conjecture due to Baxter that has been recently rigorously confirmed by Duminil-Copin et-al, states that the standard Potts model on the square lattice (Z^2) with a nearest-neighbor pair interaction exhibits a changeover phenomenon at $q_c=4$. We present a first-principle combinatorial approach based on the asymptotic growth of lattice animals with a fixed number of faces, to study the critical behavior of a q-state Potts model with a round-the-face interaction, where the system energetically favours monochromatic plaquettes.
We show that the model exhibits a first order transition for $q>3$. A second order transition is numerically detected for $q=2$. Based on these findings, it is deduced that some two-dimensional ferromagnetic Potts models with completely local interaction, obey a changeover phenomenon with $q_c<= 3$. Indeed, other studies observing a first order transition for $q<=3$ have been reported.The models in those studies, however, have a non-local and somewhat ``unnatural'' interaction content.Furthermore, a second order transition has not been uncovered in those works. Thus, in some sense, we provide a genuine simple example which stand in contrast to Baxter's conjecture.

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