Efficient Cluster Algorithms for $CP(N-1)$ Models

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Abstract: We construct efficient cluster algorithms for ferro- and antiferromagnetic $SU(N)$-symmetric quantum spin systems. Such systems provide a new regularization for $CP(N-1)$ models in the framework of D-theory, which is an alternative non-perturbative approach to quantum field theory formulated in terms of discrete quantized variables instead of classical fields. We present detailed studies of the autocorrelations and estimate a small dynamical exponent $z \approx 0.23$ for critical slowing down. Despite several attempts, no efficient cluster algorithm has been constructed for $CP(N-1)$ models at $\theta = 0$ in the standard formulation of lattice field theory. In fact, there is even a no-go theorem that prevents the construction of an efficient Wolff-type embedding algorithm. The D-theory cluster algorithm even works at non-trivial vacuum angle $\theta = \pi$, no sign problem arises in our fomulation and the θ-vacuum effects can be precisely investigated. As conjectured by Seiberg several years ago, one observes a first order phase transition with spontaneous breaking of the charge conjugation symmetry for $N \geq 3$.