Final projects for "Metodi Numerici per la Fisica"

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Module 1. "Introduction to Markov Chain Monte-Carlo with applications to statistical mechanics"

1. 2d Ising model: determination of critical properties (Metropolis single site update)

2. 2d Ising model on non-square lattices: determination of critical properties

3. 2d Ising model: determination of critical properties (cluster update)

4. 2d clock model: check that for $q = 4$ the transition is in the same universality class of the 2d Ising model

5. 3d clock model: check that for $q \geq 5$ the transition is in the same universality class of the 3d XY model

6. 2d Blume-Capel model: check that in some points of the phase diagram a transition in the 2d Ising universality class exists (see Ref. [1])

7. 3d XY model: determination of critical properties (Metropolis single site update and microcanonical update)

8. 3d XY model: determination of critical properties (cluster update)

Module 3. "Application of Monte-Carlo methods to the study of path-integral in quantum mechanics"

1. Thermodynamics and spectrum of the harmonic oscillator

2. Thermodynamics and spectrum of the harmonic oscillator with an anharmonic gx^4 correction

3. Study of the topological properties of the quantum mechanics of a particle on a circumference (local algorithms)

4. Study of the topological properties of the quantum mechanics of a particle on a circumference (parallel tempering and multicanonical update)

5. Study of the thermodynamics of a couple of identical particles (bosons and fermions) in an harmonic oscillator potential

Module 6. "Simulation of path-integral for quantum field theories"

1. Thermodynamics and spectrum of the free scalar field

2. Implementation of the HMC algorithm for the 2d U(1) gauge model and validation of the algorithm against a local update

3. Study of the static potential and topological properties of the 2d U(1) gauge model

4. Study of the static potential/string tension in the confined and deconfined phases of the 3d Z_2 gauge model (see Ref. [2] for useful strong and weak coupling expansions)

5. Study of the thermodynamics of SU(2) gauge theory in 2+1 dimensions (see [3] for the relation between the bare coupling and the lattice spacing and [4] for the critical couplings)

References

[1] J. Zierenberg, N. G. Fytas, M. Weigel, W. Janke, A. Malakis "Scaling and universality in the phase diagram of the 2D Blume-Capel model" Eur. Phys. J. Special Topics **226**, 789 (2017) [arXiv:1612.02138]

[2] J. P. Kowall and H. Neuberger "Finite size Wilson loops in Z(2)" Phys. Lett. B **106**, 197 (1981)

[3] M. J. Teper, "SU(N) gauge theories in (2+1)-dimensions" Phys. Rev. D **59**, 014512 (1999) [arXiv:9804008 [hep-lat]]

[4] S. Edwards and L. von Smekal, "SU(2) lattice gauge theory in 2+1 dimensions: Critical couplings from twisted boundary conditions and universality," Phys. Lett. B **681**, 484 (2009) [arXiv:0908.4030 [hep-lat]]