

Research Notes

Stuart Thomas and Chris Monahan

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1 Monday, June 15

1. Preliminary meeting
2. We will begin with ϕ^4 term due to lower energy bound.
3. Beginning with code in Python, switch to C/C++ if necessary.

2 Tuesday, June 16

1. Preliminary concepts to understand:
 - (a) scalar field theory on lattice
 - (b) Markov chains and Monte Carlo
 - (c) the gradient flow
 - (d) $O(n)$ symmetry
2. General components to research, executed in parallel
 - (a) Reading
 - (b) Mathematical analysis
 - (c) Writing code
 - (d) Present (writing, plot generation,...)
3. Things to get out of dissertation [6]
 - (a) Markov chain
 - (b) Cluster algorithms
 - i. Metropolis is a method for narrowing possibilities by accepting only some changes. It can get stuck in a local minimum, loss of ergodicity. We solve these with cluster algorithms. Wolff grows clusters probabilistically and flips, while Swenson and Yang identifies clusters and flips them probabilistically.
 - ii. Near a phase transition, correlation length grows and changes become less likely to be accepted: need clusters. Clusters don't work far from the phase transition. This is manifested as a sequence of a few metropolis steps and a cluster step.

4. Research plan

- (a) Start with 2D ϕ^4
 - i. Set up lattice with sign flip for reflection
 - ii. Use Markov chain Monte Carlo to simulate.
 - iii. Measure, magnetization and susceptibility, Binder cumulant
- (b) Transition to 3D, then maybe transition to C/C++.
- (c) Implement the gradient flow
- (d) move to 2-3d nonlinear sigma model.
- (e) Motivation: the nonlinear sigma model works for QCD given the asymptotic freedom. We may also want to explore topology.

3 Wednesday, June 17

1. Code tips:

- (a) Try Swendsen-Wang algorithm in addition to Wolff
- (b) Print out time taken
- (c) Optimize Hamiltonian
- (d) Save every tenth measurement or store configurations to calculate path integral. Exclude thermalization (first 200)
- (e) Write in terms of sweeps, not iterations
- (f) Parallelize (look into checkerboard algorithm)
- (g) Implement Binder cumulant and susceptibility
- (h) Store every few states
- (i) Look into multigrid algorithm

2. Reading on Monte Carlo Markov chain and cluster algorithms.

References

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- [2] H. Makino, F. Sugino, and H. Suzuki. Large- n limit of the gradient flow in the 2D $o(n)$ nonlinear sigma model. *Progress of Theoretical and Experimental Physics*, 2015(4):43B07–0, 2015.
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- [6] D. Schaich and W. Loinaz. *Lattice Simulations of Nonperturbative Quantum Field Theories*. PhD thesis, Amherst College, Amherst, MA, 2006.