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Book Review: *Monte Carlo Methods in Statistical Physics*

Monte Carlo Methods in Statistical Physics. M. E. J. Newman and G. T. Barkema, Clarendon Press, Oxford, 1999.

A graduate student starting a research project in simulation physics might get the idea that the Metropolis algorithm is the main technique for modeling systems in thermal equilibrium. In this well written book, though, Newman and Barkema show very clearly that as venerable as it is, the Metropolis algorithm is not the only or even best game in town. Focusing narrowly on the Ising model (with some discussion of other spin models, ice models and the repton model of DNA migration in gels), the authors nonetheless present an almost encyclopedic account of Monte Carlo algorithms and the necessary data analysis techniques of computer-generated results.

The first chapter is a short, basic review of statistical mechanics which ends with delightful section about the history of Monte Carlo methods, starting with "Buffon's needle" trick (devised in 1777!) and continuing to the introduction of modern computers that made simulation practical. It's a pity that this historical discussion wasn't expanded into a full chapter, but as traditional science education tends to ignore science history this section is still a major service to a new student. The second chapter is the fundamental core of the book with a detailed discussion of the importance of ergodicity, and detailed balance: both of which must be satisfied by any algorithm that uses a Markovian process to flip Ising spins in order to mimic thermal equilibrium. (In fact, throughout the whole book the authors pay attention to ergodicity and detailed balance whenever they introduce an algorithm.) The third chapter introduces the Metropolis algorithm for single spin flips and discusses data analysis of some real simulations. This chapter ends with an example that highlights the great weakness of the Metropolis algorithm: "critical slowing down," the divergence of the time that spin flips are correlated at temperatures near a phase transition. (A finite model can not have a true phase transition, but even in a finite model the correlation length between spins can become the size of a lattice.)

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The next chapter introduces the Wolff algorithm and other procedures which try to flip clusters of spins and thus are better suited for simulation in the critical regime.

The rest of the chapters are similar in their thoroughness and attention to detail. Among other topics discussed are simulations of Ising models with conserved order parameters, entropic sampling and its application to disordered spin models, ice models, overcoming finite size effects, Swendsen's clever blending of Monte Carlo techniques with ideas from renormalization group theory to find the critical temperature, and certain non-equilibrium situations. The last four chapters deal with actual programming techniques needed to implement a Monte-Carlo simulation. Some of the discussion in the last chapters is very elementary to an experience programmer, but overall they are a good reference. The chapter about parallel implementation of Monte-Carlo algorithms illustrates the honesty and no-nonsense approach of the authors: they point out that even though domain decomposition allows parallel processing to boost the speed of Monte Carlo methods, the communication costs between processors still prevents Monte Carlo methods from being as scalable as other numerical techniques.

Overall, the technical level of that of a graduate text, though an advanced undergraduate and the experience researcher would both benefit from reading this book. I would strongly recommend it as a textbook for a course in simulation methods or as a supplementary text in a statistical physics course. It style is very readable although the attention to detail makes some sections tough to absorb in a single sitting. But that is not necessary a bad thing. And there are problems to solve after almost every chapter. The one criticism that I have is that fermion systems are totally ignored. Working physicists in condensed matter have to deal with electrons and I wish that the authors had a discussion of the special problems of fermionic simulation. The exclusion principle forces even the most simple-to-formulate fermion system such as the Hubbard model to be as complex as an Ising lattice with non-local, time dependent interactions. If the authors ever write a second edition, perhaps they could include a brief chapter about fermions with a list of references to those researchers who have toiled over them. But this edition is still outstanding.

Philip G. McQueen
Center for Information Technology
National Institutes of Health
Bethesda, Maryland 20892-5624