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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, Oxford University Press, 1999.

In recent years there has been a flurry of activity in the development of new Monte Carlo algorithms that accelerate the dynamics of particular classes of systems in statistical physics. The present text discusses many of these algorithms including several cluster algorithms, multigrid methods, entropic sampling, simulated tempering, and continuous time Monte Carlo. Classical systems of interest include the nearest neighbor Ising model, the Ising spin glass, ice models, lattice gases, surface diffusion models, and the repton model of polymer electrophoresis.

The authors assume that the reader has a working knowledge of classical statistical mechanics and thermodynamics at the level typical of a student beginning graduate study in physics. They give a brief outline of the basic physics of each model and do not assume that the reader is familiar with the models that are discussed. The text teaches by example and discusses the results of most of the algorithms in the context of a relevant model. The many figures illustrate the main points well. Problems are given at the end of each chapter and answers are given to the analytical problems and hints are given for the problems that require writing a computer program.

The sixteen chapters are grouped into three parts covering equilibrium Monte Carlo simulations, non-equilibrium simulations, and implementation. After a brief introduction to statistical mechanics and the nature of importance sampling in the first two chapters, the Ising model and the Metropolis algorithm are discussed in Chapter 3. Although discussions of these topics can be found in many texts, the authors introduce these topics clearly and concisely. They also discuss the calculation of errors including the bootstrap and jackknife methods. As they do in most of the other chapters, they also discuss an actual calculation of various properties of the two-dimensional Ising model and introduce critical slowing down and

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other relevant concepts. Chapter 4 introduces other important algorithms for the Ising model including the Wolff and Swendsen algorithms, and the lesser known Niedermayer algorithm, multigrid methods, and the invaded cluster algorithm. I particularly enjoyed the discussion of how the Metropolis and Wolff algorithms satisfy detailed balance. Chapter 5 discusses the conserved order parameter Ising model, the Kawasaki algorithm, and continuous time Monte Carlo in the context of equilibrium crystal shapes. Chapter 6 discusses the entropic sampling method and simulated tempering in the context of the random field Ising model and Ising spin glass. Chapter 7 discusses various lattice models of ice, one of the research interests of the authors, and Chapter 8 discusses ways of analyzing Monte Carlo data including the single and multiple histogram methods, finite size scaling, and estimating critical exponents using Monte Carlo renormalization group methods. Chapters 9–12 discuss various simulations of non-equilibrium situations including phase separation and domain growth in the conserved order parameter Ising model, surface diffusion, and the repton model. Chapters 13–16 present the implementation of the various methods using various data structures, multispin coding, and generating random numbers. The sample C programs given in an appendix should help many readers understand many of the algorithms. However, contrary to the claim of the authors, Fortran does provide bit manipulation operators appropriate for implementing multispin coding. Fortran lives! I learned something from every chapter, although the least interesting chapters to me were those on the ice model and reptons which were clearly motivated by the authors' current research.

The book is well written and can be enjoyed at various levels. The style is informal, and abbreviations are used such as "we're" and "don't." The word "hard" is used instead of "difficult." I'll just have to get used to it. I learned the meaning of the phrase "it's horses for courses" in the context of the relative merits of entropic sampling and simulated tempering. Among the nuggets of wisdom is the statement that "… the demarcation of science into the separate disciplines of physics, biology, chemistry and so forth is, after all, an artifact of our own creation, and has little to do with the science involved."

The influence of Monte Carlo methods in statistical physics is so pervasive that the authors can write over 400 pages without discussing the application of Monte Carlo methods to continuum systems. Although the coverage of the text is comprehensive, I found myself wishing in places that the authors had explained the associated physics more deeply and the associated theory whenever it exists. A more extensive list of references would have added to the usefulness of the text. However, the primary goal of the book is to explain how to perform Monte Carlo simulations efficiently, and the authors have succeeded admirably in achieving their goal.

The authors' discussion of the results of the algorithms was very helpful in understanding the algorithms. It would have been even more instructive if the authors were to make their data accessible on the Web so that readers could analyze the data themselves, even though readers will learn more if they write their own programs and generate their own data.

In summary, this book belongs in the personal library of all researchers in statistical physics (regardless of whether they write Monte Carlo algorithms or not), computational scientists interested in Monte Carlo methods, and advanced undergraduates and graduate students wishing to learn about recent developments in statistical physics and Monte Carlo methods.

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