BOOK REVIEW

PARALLEL AND DISTRIBUTED COMPUTATION: NUMERICAL METHODS

Dimitri P. Bertsekas and John N. Tsitsiklis. 1989. Englewood Cliffs, New Jersey: Prentice-Hall. 715 pp. $40.

Parallel and distributed computation has been studied and written about from various perspectives, ranging from the hardware design of parallel machines to the details of coding parallel programs. Lacking, however, has been a unified treatment of algorithms for broad classes of problems with applications in many different disciplines. This rich tome by Bertsekas and Tsitsiklis is a timely contribution and fills the void.

This highly readable book focuses on numerical methods for solving systems of equations and optimization problems. Using a theoretical, machine-independent framework, the book emphasizes the analysis and design of algorithms that admit a high degree of parallelism with the ultimate goal of enabling the solution of problems much larger than heretofore possible. It includes an overview of existing parallel and distributed computing systems and describes measures for evaluating alternative parallel algorithms.

Designed as a graduate text for use in the authors' course at MIT, this book could be used for courses in engineering, computer science, operations research, and applied mathematics. It is essentially a self-contained work, with the development of the material occurring in the main body of the text and excellent appendices on linear algebra and analysis, graph theory, duality theory, and probability theory and Markov chains supporting it.

The introduction discusses parallel and distributed architectures, complexity measures, and communication and synchronization issues, and it presents both Jacobi and Gauss-Seidel iterations, which serve as algorithms of reference for many of the computational approaches addressed later. After the introduction, the text is organized in two parts: synchronous algorithms and asynchronous algorithms.

The discussion of synchronous algorithms comprises four chapters, with Chapter 2 presenting both direct methods (converging to the exact solution within a finite number of steps) and iterative methods for linear systems of equations and matrix inversions. Included are parallel implementations of earlier serial algorithms and algorithms developed with the goal of better exploiting parallelism.

Chapter 3 considers iterative methods for nonlinear problems, including nonlinear equations, optimization problems, and variational inequalities. Systems of nonlinear equations and optimization problems arise in many types of mathematical models in both engineering and the social sciences. One of the highlights of the book is the inclusion of variational inequalities, which can be viewed as generalizing both systems of equations and constrained optimization problems. Variational inequalities can be used to model equilibrium problems in distinct disciplines, including transportation network equilibrium problems, economic equilibrium, and game theoretic problems. The chapter discusses the convergence of iterative methods in depth by utilizing the theory of contraction mappings and by establishing that the cost function of the underlying optimization problem is reduced iteratively. The algorithms emphasized are of the Jacobi and Gauss-Seidel type, with special emphasis on the structure of the constraint sets that lend themselves to decomposition and, hence, parallelism.

Chapter 4 discusses the classical combinatorial problem—the shortest

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path problem. The shortest path problem appears in a plethora of applications, including the routing of data within computer communication networks, and arises as a subproblem to be solved frequently in other, more complicated problems. The authors then turn to the more general dynamic programing problem.

Chapter 5 deals with network flow problems, which are the most frequently solved class of optimization problems. They include, as special cases, the aforementioned shortest path problem and the classical transportation problem. Network flow problems appear in the study of complex systems in manufacturing, transportation, and logistics, and communications. The chapter begins with linear network flow problems and then proceeds to strictly convex problems. The parallelizable algorithms discussed here can be viewed as relaxation methods applied in the space of dual variables and, again, are conceptually related to the Jacobi and Gauss-Seidel methods. The chapter concludes with a discussion of nonlinear multicommodity flow problems.

The second half of the book is devoted to asynchronous algorithms and contains much new material not published elsewhere. Asynchronous algorithms, unlike synchronous ones, do not have to wait at predetermined points for messages to become available. One expects that the gains from asynchronism would be both a decrease in the penalty of synchronization and a potential speed advantage, but at a potential cost of arbitrarily large communication delays. Here the authors develop the asynchronous versions of the major types of synchronous algorithms described in the first half of the book.

In Chapter 6, besides discussing asynchronous iterative algorithms, the authors present a very useful general theorem for establishing convergence of totally asynchronous algorithms. They also compare the convergence rates of synchronous and asynchronous algorithms.

Chapter 7 moves on to partially asynchronous algorithms and distinguishes the analysis and convergence mechanism from that developed for totally asynchronous algorithms.

The book concludes with "generic" issues in the organization of an asynchronous network for the purpose of executing a general type of parallel algorithm.

This handsome edition has geometric interpretations of algorithms presented throughout and many illuminating illustrations. The problem sets contained in the chapters enhance the book's pedagogical intentions. At the same time, the book can serve as an invaluable introduction to the state of the art for scientists in distinct disciplines who are interested in applying parallel algorithms for the computation of their large-scale applications. Finally, it challenges the research scientist who is focusing on parallel algorithm development to tackle many open problems that are suggested by the text.

This major contribution to the literature belongs on the bookshelf of every scientist with an interest in computational science, directly beside Knuth's three volumes and *Numerical Recipes*, by Press, Flannery, Teukolsky, and Vetterling.

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