4[65–01, 65Fxx].—GENE H. GOLUB & CHARLES F. VAN LOAN, *Matrix Computations*, Johns Hopkins Series in the Mathematical Sciences, Vol. 3, The Johns Hopkins University Press, 2nd ed., 1989, xix + 642 pp., 24 cm. Price \$59.50 hardcover, \$29.95 paperback.

I was somewhat apprehensive when I hefted the second edition of *Matrix Computation* and found it heavier than the first by about one hundred and fifty pages. Too often a good book is ruined in its second edition. It grows in size, but not in substance, as the author adds extraneous topics. Lively passages are replaced by ponderously correct ones. The very structure of the book seems to weaken so that it diffuses knowledge rather than channeling it.

The second edition of *Matrix Computations*, I am happy to say, avoids these pitfalls. The first edition had quickly established itself as the definitive reference on numerical linear algebra. It was necessarily incomplete, owing to the size of the field; but it was judicious in its selection of topics, and its exercises and extensive bibliographical notes pointed the reader to areas for further study. Moreover, it was well written. All this and more can be said of the second edition.

Since the first edition was reviewed extensively when it appeared (for a review in this journal, see [1]), I will only sketch the contents of the second and then focus on the differences between the editions.

The book begins with the basics: a chapter that uses matrix multiplication to explain the issues in implementing matrix algorithms and a chapter on matrix analysis, including norms and elementary perturbation theory. The next three chapters treat linear systems—general and special—and linear least squares problems. Then follows a new chapter on parallel matrix computations. The next two chapters treat dense eigenvalue problems, unsymmetric and symmetric. The authors make their bow to sparse matrix computations with two chapters on the Lanczos and conjugate gradient algorithms and conclude with two chapters on special topics.

The changes from the first to the second edition may be arranged in four overlapping categories: new notation, new orientation, new algorithms, and a new chapter on parallel matrix computations. The notational change is the language used to describe algorithms, which is now loosely based on MATLAB. The advantage is that it allows algorithms to be written in terms of submatrices rather than scalars and fits hand in glove with the new orientation, to which I now turn.

One of the most exciting developments in matrix computations over the last decade has been the increasing abstraction with which matrix algorithms are expressed. The trend started with the basic linear algebra subprograms (BLAS) for vector operations, which were used with success in LINPACK. However, the vector BLAS did not solve the problems associated with virtual memories; and, surprisingly, they did not perform optimally on some vector computers. The second step was to introduce new subprograms, the BLAS2, that operate at the matrix-vector level; e.g., programs to multiply a matrix by a vector or add a rank-one matrix to another matrix. More recently, the emphasis has been on block algorithms that permit matrix-matrix operations as the unit of computation.

The spirit of this development completely informs the new edition. Many old algorithms have been written in a form suitable for implementation with the BLAS2, and new block algorithms are presented. In addition, there is a revised treatment of the Jacobi method and new material on the Arnoldi algorithm and the method of preconditioned conjugate gradients. If I had to select the one most significant improvement in the book, it would be this thorough reworking of the algorithms.

Only time will tell whether the authors' decision to include a long chapter on parallel matrix computations was courageous or foolhardy. It is a timely topic, and the authors serve the research community well with their clear exposition of the issues and techniques. They treat algorithms on global and distributed memory systems, with particular attention paid to the problems of synchronization and communication. However, the area is in a state of flux, and there is a chance that the chapter will have to be entirely rewritten in later editions. An unfortunate side effect of the inclusion of this chapter is that the authors' treatment of pipelined vector computing is sketchy and inconclusive. To treat both topics in detail would have overloaded the book, and the authors' choice is easily defended; but it slants the book away from the practitioner and toward the researcher.

In their exercises and bibliographical notes the authors maintain the high standard they set for themselves in the first edition. They continue the useful practice of giving full references on the spot, while also providing a complete bibliography at the end of the book. The bibliography itself has been expanded and includes references dating to just before publication. It is *the* place to begin a search for references on the topics treated in the book.

The publishers, unfortunately, have not taken the same pains as the authors. The layout is vanilla LaTeX—a serviceable format, but too much in evidence nowadays. More disturbing, the publishers use a low resolution printing device to prepare the book, and the effect of the blurry chapter and section heads may be likened to fingernails grating over a blackboard. The authors and their readers deserve better of The Johns Hopkins University Press.

But to judge by content rather than appearance, this is in every way an excellent book. It belongs on the desk of anyone with an interest in numerical linear algebra. The authors have clearly worked hard to incorporate the most recent advances in the area into the new addition, and we are greatly in their debt.

G. W. S.

1. D. F. Mayers, Review **24**, Math. Comp. **47** (1986), 376–377.