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Roger A. Horn and Charles R. Johnson
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TOPICS IN MATRIX ANALYSIS

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Topics in matrix analysis

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Preface

This volume is a sequel to the previously published *Matrix Analysis* and includes development of further topics that support applications of matrix theory. We refer the reader to the preface of the prior volume for many general comments that apply here also. We adopt the notation and referencing conventions of that volume and make specific reference to it [HJ] as needed.

Matrix Analysis developed the topics of broadest utility in the connection of matrix theory to other subjects and for modern research in the subject. The current volume develops a further set of slightly more specialized topics in the same spirit. These are: the field of values (or classical numerical range), matrix stability and inertia (including M-matrices), singular values and associated inequalities, matrix equations and Kronecker products, Hadamard (or entrywise) products of matrices, and several ways in which matrices and functions interact. Each of these topics is an area of active current research, and several of them do not yet enjoy a broad exposition elsewhere.

Though this book should serve as a reference for these topics, the exposition is designed for use in an advanced course. Chapters include motivational background, discussion, relations to other topics, and literature references. Most sections include exercises in the development as well as many problems that reinforce or extend the subject under discussion. There are, of course, other matrix analysis topics not developed here that warrant attention. Some of these already enjoy useful expositions; for example, totally positive matrices are discussed in [And] and [Kar].

We have included many exercises and over 650 problems because we feel they are essential to the development of an understanding of the subject and its implications. The exercises occur throughout the text as part of the

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development of each section; they are generally elementary and of immediate use in understanding the concepts. We recommend that the reader work at least a broad selection of these. Problems are listed (in no particular order) at the end of sections; they cover a range of difficulties and types (from theoretical to computational) and they may extend the topic, develop special aspects, or suggest alternate proofs of major ideas. In order to enhance the utility of the book as a reference, many problems have hints; these are collected in a separate section following Chapter 6. The results of some problems are referred to in other problems or in the text itself. We cannot overemphasize the importance of the reader's active involvement in carrying out the exercises and solving problems.

As in the prior volume, a broad list of related books and major surveys is given prior to the index, and references to this list are given via mnemonic code in square brackets. Readers may find the reference list of independent utility.

We appreciate the assistance of our colleagues and students who have offered helpful suggestions or commented on the manuscripts that preceded publication of this volume. They include M. Bakonyi, W. Barrett, O. Chan, C. Cullen, M. Cusick, J. Dietrich, S. H. Friedberg, S. Gabriel, F. Hall, C.-K. Li, M. Lundquist, R. Mathias, D. Merino, R. Merris, P. Nylen, A. Sourour, G. W. Stewart, R. C. Thompson, P. van Dooren, and E. M. E. Wermuth.

The authors wish to maintain the utility of this volume to the community and welcome communication from readers of errors or omissions that they find. Such communications will be rewarded with a current copy of all known errata.

R. A. H.
C. R. J.

Preface to the Second Printing

We have corrected all known errata in the first printing, polished the exposition of a few points, noted the resolution of several conjectures, and added some items to the notation list and index. It is a pleasure to acknowledge helpful comments from our colleagues T. Ando, R. Bhatia, S. Friedberg, D. Jesperson, B. Kroschel, I. Lewkowicz, C.-K. Li, R. Loewy, J. Miao, and F. Uhlig.

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