Direct algorithms of solution of eigenvalue problem

6

INTRODUCTION

In the last two chapters, we studied the algorithms for linear equations Ax = b. In this and next chapter, we study the algorithms for an eigenvalue problem. The eigenvalue problem is to find λ and x from the equation $Ax = \lambda x$ or $Ax = \lambda Bx$, where A and B are two square matrices. About the mathematical theories and properties of an eigenvalue problem, see Section 1.4 for a brief exposition or [29] for a more detailed discussion.

For $A \in \mathbb{R}^{m \times n}$, the eigenvalue λ is the root of the nth order polynomial $\det(A - \lambda I) = 0$. Similarly for $A, B \in \mathbb{R}^{m \times n}$, the generalized eigenvalue λ is the root of the nth order polynomial $\det(A - \lambda B) = 0$. If n = 1, the calculation of the eigenvalue is truly trivial. If n = 2, 3, 4, direct algorithms are possible. These direct algorithms actually can be used as building blocks for iterative algorithms for n > 4. In Section 6.1, we list two MATLAB functions to calculate the eigenvalues for the case n = 2. If n > 4, no direct algorithms are possible. However, the algorithms presented in this chapter are like direct algorithms in real applications: the experience shows that they (nearly) never fail to converge in a fixed number of iterations. In the next chapter, we study the other iterative algorithms that do not have these preferred characteristics.

In Section 6.2, we present four useful auxiliary algorithms for the symmetric eigenvalue problem. For a symmetric matrix $A \in \mathbb{R}^{n \times n}$, its eigenvalues are real and thus can be ordered ascendingly, $\lambda_1 \leq \lambda_2 \leq \cdots \leq \lambda_{n-1} \leq \lambda_n$. The first algorithm, which is implemented in neig...m, calculates an integer pair $[k,l], k \leq l$ from a given interval $[\alpha,\beta], \alpha \leq \beta$, such that $\alpha \leq \lambda_k$ and $\lambda_l \leq \beta$. The second algorithm, which is implemented in neig...m, is the inverse function of neig...m. The two algorithms are useful when only approximate bound for an eigenvalue is needed. There are two similar algorithms, vzeig...m and rzeig...m, for the symmetric positive definite generalized eigenvalue problem.

The key algorithm of the chapter is QR iteration algorithm, which is presented in Section 6.4. QR iteration is an extension of the power iteration and subspace iteration method. The power iteration and subspace iteration methods do not belong to the 'direct' eigenvalue algorithms that are the topic of this chapter. We defer their full presentation in the next chapter. However, we start the presentation of QR algorithm with a brief introduction of the two algorithms in Section 6.3. Two algorithms, eigunsymbyqR_n and eigSymbyqR_n, are presented in Section 6.4. The second one is a specialized QR algorithm for symmetric matrices.

Section 6.5 presents the inverse iteration algorithm to calculate the eigenvectors from the given eigenvalues. Section 6.6 presents an orthogonal similarity transformation to order the eigenvalues in real Schur form of an unsymmetric matrix. The algorithm is useful to obtain the invariant subspace corresponding to the given eigenvalues of an unsymmetric matrix.

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Resende, Chrysafis Vogiatzis, Jose L. Walteros, 2014-07-31 This book constitutes the thoroughly refereed post conference proceedings of the 8th International Conference on Learning and Optimization LION 8 which was held in Gainesville FL USA in February 2014 The 33 contributions presented were carefully reviewed and selected for inclusion in this book A large variety of topics are covered such as algorithm configuration multiobjective optimization metaheuristics graphs and networks logistics and transportation and biomedical applications NEO 2016 Yazmin Maldonado, Leonardo Trujillo, Oliver Schütze, Annalisa Riccardi, Massimiliano Vasile, 2017-09-12 This volume comprises a selection of works presented at the Numerical and Evolutionary Optimization NEO 2016 workshop held in September 2016 in Tlalnepantla Mexico The development of powerful search and optimization techniques is of great importance in today s world and requires researchers and practitioners to tackle a growing number of challenging real world problems In particular there are two well established and widely known fields that are commonly applied in this area i traditional numerical optimization techniques and ii comparatively recent bio inspired heuristics Both paradigms have their unique strengths and weaknesses allowing them to solve some challenging problems while still failing in others The goal of the NEO workshop series is to bring together experts from these and related fields to discuss compare and merge their complementary perspectives in order to develop fast and reliable hybrid methods that maximize the strengths and minimize the weaknesses of the underlying paradigms In doing so NEO promotes the development of new techniques that are applicable to a broader class of problems Moreover NEO fosters the understanding and adequate treatment of real world problems particularly in emerging fields that affect all of us such as healthcare smart cities big data among many others. The extended papers presented in the book contribute to achieving this goal The Design of Innovation David E. Goldberg, 2013-03-14 7 69 6 A DESIGN APPROACH TO PROBLEM DIFFICULTY 71 1 Design and Problem Difficulty 71 2 Three Misconceptions 72 3 Hard Problems Exist 76 4 The 3 Way Decomposition and Its Core 77 The Core of Intra BB Difficulty Deception 5 77 6 The Core of Inter BB Difficulty Scaling 83 7 The Core of Extra BB Difficulty Noise 88 Crosstalk All Roads Lead to the Core 8 89 9 From Multimodality to Hierarchy 93 10 Summary 100 7 ENSURING BUILDING BLOCK SUPPLY 101 1 Past Work 101 2 Facetwise Supply Model I One BB 102 Facetwise Supply Model II Partition Success 103 3 4 Population Size for BB Supply 104 Summary 5 106 8 ENSURING BUILDING BLOCK GROWTH 109 1 The Schema Theorem BB Growth Bound 109 2 Schema Growth Somewhat More Generally 111 3 Designing for BB Market Share Growth 112 4 Selection Press ure for Early Success 114 5 Designing for Late in the Day 116 The Schema Theorem Works 6 118 A Demonstration of Selection Stall 7 119 Summary 122 8 9 MAKING TIME FOR BUILDING BLOCKS 125 1 Analysis of Selection Alone Takeover Time 126 2 Drift When Selection Chooses for No Reason 129 3 Convergence Times with Multiple BBs 132 4 A Time Scales Derivation of Critical Locus 142 5 A Little Model of Noise Induced Run Elongation 143 6 From Alleles to Building Blocks 147 7 Summary 148 10 DECIDING WELL 151 1 Why is Decision Making a Problem 151 Elements of Programming Interviews Adnan Aziz, Tsung-Hsien Lee, Amit Prakash, 2012

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