

Direct algorithms of solution of eigenvalue problem

INTRODUCTION

In the last two chapters, we studied the algorithms for linear equations $\mathbf{Ax} = \mathbf{b}$. In this and next chapter, we study the algorithms for an eigenvalue problem. The eigenvalue problem is to find λ and $\mathbf{x}$ from the equation $\mathbf{Ax} = \lambda\mathbf{x}$ or $\mathbf{Ax} = \lambda\mathbf{Bx}$, where $\mathbf{A}$ and $\mathbf{B}$ 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 $\mathbf{A} \in \mathbb{R}^{n \times n}$, the eigenvalue λ is the root of the n th order polynomial $\det(\mathbf{A} - \lambda\mathbf{I}) = 0$. Similarly for $\mathbf{A}, \mathbf{B} \in \mathbb{R}^{n \times n}$, the generalized eigenvalue λ is the root of the n th order polynomial $\det(\mathbf{A} - \lambda\mathbf{B}) = 0$. 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 $\mathbf{A} \in \mathbb{R}^{n \times n}$, 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 `seig.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 `seig2.m`, is the inverse function of `seig.m`. The two algorithms are useful when only approximate bound for an eigenvalue is needed. There are two similar algorithms, `vseig.m` and `rvseig.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.m` and `eigSymByQR.m`, 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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subjects of the book It is a must have for bioinformaticians computer scientists and molecular biologists Computer Science Subrata Dasgupta,2016-03-24 Over the past sixty years the spectacular growth of the technologies associated with the computer is visible for all to see and experience Yet the science underpinning this technology is less visible and little understood outside the professional computer science community As a scientific discipline computer science stands alongside the likes of molecular biology and cognitive science as one of the most significant new sciences of the post Second World War era In this Very Short Introduction Subrata Dasgupta sheds light on these lesser known areas and considers the conceptual basis of computer science Discussing algorithms programming and sequential and parallel processing he considers emerging modern ideas such as biological computing and cognitive modelling challenging the idea of computer science as a science of the artificial ABOUT THE SERIES The Very Short Introductions series from Oxford University Press contains hundreds of titles in almost every subject area These pocket sized books are the perfect way to get ahead in a new subject quickly Our expert authors combine facts analysis perspective new ideas and enthusiasm to make interesting and challenging topics highly readable **Metaheuristic Clustering** Swagatam Das,Ajith Abraham,Amit Konar,2009-01-30 Cluster analysis means the organization of an unlabeled collection of objects or patterns into separate groups based on their similarity The task of computerized data clustering has been approached from diverse domains of knowledge like graph theory multivariate analysis neural networks fuzzy set theory and so on Clustering is often described as an unsupervised learning method but most of the traditional algorithms require a prior specification of the number of clusters in the data for guiding the partitioning process thus making it not completely unsupervised Modern data mining tools that predict future trends and behaviors for allowing businesses to make proactive and knowledge driven decisions demand fast and fully automatic clustering of very large datasets with minimal or no user intervention In this volume we formulate clustering as an optimization problem where the best partitioning of a given dataset is achieved by minimizing maximizing one single objective clustering or more multi objective clustering objective functions Using several real world applications we illustrate the performance of several metaheuristics particularly the Differential Evolution algorithm when applied to both single and multi objective clustering problems where the number of clusters is not known beforehand and must be determined on the run This volume comprises of 7 chapters including an introductory chapter giving the fundamental definitions and the last Chapter provides some important research challenges Academics scientists as well as engineers engaged in research development and application of optimization techniques and data mining will find the comprehensive coverage of this book invaluable **Smart Systems and Wireless Communication** Rituparna Chaki,Agostino Cortesi,Suparna DasGupta,Soumyabrata Saha,2025-05-19 The volume is a collection of high quality research papers presented at International Conference on Smart Systems and Wireless Communication SSWC 2024 organized Department of Information Technology JIS College of Engineering Kalyani West Bengal India during 29 30 November 2024 This book focuses smart

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Multi Objective Combinatorial Optimization Problems and Solution Methods discusses the results of a recent multi objective combinatorial optimization achievement that considered metaheuristic mathematical programming heuristic hyper heuristic and hybrid approaches In other words the book presents various multi objective combinatorial optimization issues that may benefit from different methods in theory and practice Combinatorial optimization problems appear in a wide range of applications in operations research engineering biological sciences and computer science hence many optimization approaches have been developed that link the discrete universe to the continuous universe through geometric analytic and algebraic techniques This book covers this important topic as computational optimization has become increasingly popular as design optimization and its applications in engineering and industry have become ever more important due to more stringent design requirements in modern engineering practice Presents a collection of the most up to date research providing a complete overview of multi objective combinatorial optimization problems and applications Introduces new approaches to handle different engineering and science problems providing the field with a collection of related research not already covered in the primary literature Demonstrates the efficiency and power of the various algorithms problems and solutions including numerous examples that illustrate concepts

and algorithms **The ^ASecond Age of Computer Science** Subrata Dasgupta,2018-05-01 Between the genesis of computer science in the 1960s and the advent of the World Wide Web around 1990 computer science evolved in significant ways The author has termed this period the second age of computer science This book describes its evolution in the form of several interconnected parallel histories **Advanced Solutions in Power Systems** Mircea Eremia,Chen-Ching Liu,Abdel-Aty Edris,2016-10-03 Provides insight on both classical means and new trends in the application of power electronic and artificial intelligence techniques in power system operation and control This book presents advanced solutions for power system controllability improvement transmission capability enhancement and operation planning The book is organized into three parts The first part describes the CSC HVDC and VSC HVDC technologies the second part presents the FACTS devices and the third part refers to the artificial intelligence techniques All technologies and tools approached in this book are essential for power system development to comply with the smart grid requirements Discusses detailed operating principles and diagrams theory of modeling control strategies and physical installations around the world of HVDC and FACTS systems Covers a wide range of Artificial Intelligence techniques that are successfully applied for many power system problems from planning and monitoring to operation and control Each chapter is carefully edited with drawings and illustrations that helps the reader to easily understand the principles of operation or application Advanced Solutions in Power Systems HVDC FACTS and Artificial Intelligence is written for graduate students researchers in transmission and distribution networks and power system operation This book also serves as a reference for professional software developers and practicing engineers Multiobjective Heuristic Search Pallab Dasgupta,P. P. Chakrabarti,S. C. DeSarkar,2013-11-11 A large number of problems require the optimization of multiple criteria These criteria are often non commensurate and sometimes conflicting in nature making the task of optimization more difficult In such problems the task of creating a combined optimization function is often not easy Moreover the decision procedure can be affected by the sensitivity of the solution space and the trade off is often non linear In real life we traditionally handle such problems by suggesting not one but several non dominated solutions Finding a set of non dominated solutions is also useful in multistaged optimization problems where the solution of one stage of optimization is passed on to the next stage One classic example is that of circuit design where high level synthesis logic synthesis and layout synthesis comprise important stages of optimization of the circuit Passing a set of non dominated partial solutions from one stage to the next typically ensures better global optimization This book presents a new approach to multi criteria optimization based on heuristic search techniques Classical multicriteria optimization techniques rely on single criteria optimization algorithms and hence we are either required to optimize one criterion at a time under constraints on the others or we are asked for a single scalar combined optimization function On the other hand the multiobjective search approach maps each optimization criterion onto a distinct dimension of a vector valued cost structure **Operations Research and Management Science Handbook** A. Ravi Ravindran,2016-04-19 Operations

Research OR began as an interdisciplinary activity to solve complex military problems during World War II Utilizing principles from mathematics engineering business computer science economics and statistics OR has developed into a full fledged academic discipline with practical application in business industry government and m *Advances in Linear Matrix Inequality Methods in Control* Laurent El Ghaoui,Silviu-Iulian Niculescu,2000-01-01 Linear matrix inequalities LMIs have recently emerged as useful tools for solving a number of control problems This book provides an up to date account of the LMI method and covers topics such as recent LMI algorithms analysis and synthesis issues nonconvex problems and applications It also emphasizes applications of the method to areas other than control **Algorithmic Applications in Management** Nimrod Megiddo,Yinfeng Xu,Nancy Alonstioti,Binhai Zhu,2005-06-02 This book constitutes the refereed proceedings of the First International Conference on Algorithmic Applications in Management AAIM 2005 held in Xian China in June 2005 The 46 revised full papers presented together with abstracts of 2 invited talks were carefully reviewed and selected from 140 submissions Among the topics addressed are approximation complexity automatic timetabling scheduling algorithms game theoretic algorithms economic equilibrium computation graph computations network algorithms computational geometry combinatorial optimization sequencing network management data mining Knapsack problems etc

Models and Algorithms for Biomolecules and Molecular Networks Bhaskar DasGupta,Jie Liang,2016-01-07 By providing expositions to modeling principles theories computational solutions and open problems this reference presents a full scope on relevant biological phenomena modeling frameworks technical challenges and algorithms Up to date developments of structures of biomolecules systems biology advanced models and algorithms Sampling techniques for estimating evolutionary rates and generating molecular structures Accurate computation of probability landscape of stochastic networks solving discrete chemical master equations End of chapter exercises Reversible Logic Synthesis Methodologies with Application to Quantum Computing Saleem Mohammed Ridha Taha,2015-09-24 This book opens the door to a new interesting and ambitious world of reversible and quantum computing research It presents the state of the art required to travel around that world safely Top world universities companies and government institutions are in a race of developing new methodologies algorithms and circuits on reversible logic quantum logic reversible and quantum computing and nano technologies In this book twelve reversible logic synthesis methodologies are presented for the first time in a single literature with some new proposals Also the sequential reversible logic circuitries are discussed for the first time in a book Reversible logic plays an important role in quantum computing Any progress in the domain of reversible logic can be directly applied to quantum logic One of the goals of this book is to show the application of reversible logic in quantum computing A new implementation of wavelet and multiwavelet transforms using quantum computing is performed for this purpose Researchers in academia or industry and graduate students who work in logic synthesis quantum computing nano technology and low power VLSI circuit design will be interested in this book Learning and Intelligent Optimization Panos M. Pardalos,Mauricio G.C.

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 Tlalneantla 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 Pressure 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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