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Solution of $f(A)x = b$ with Krylov subspace information

11.1 Introduction

In this chapter, I expand on an idea for exploiting Krylov subspace information obtained for the matrix A and the vector b. This subspace information can be used for the approximate solution of a linear system $f(A)x = b$, where f is some analytic function, $A \in \mathbb{R}^{n \times n}$, and $b \in \mathbb{R}^n$. I will make suggestions on how to use this for the case where f is the matrix *sign* function. The matrix *sign* function plays an important role in QCD computations, see for instance [147].

In [197] an approach was suggested for the use of a Krylov subspace for the computation of approximate solutions of linear systems

$$f(A)x = b.$$

The approach was motivated by the function $f(A) = A^2$, which plays a role in the solution of some biharmonic systems. The approach is easily generalized for nonsymmetric complex matrices, but we may have to pay more attention to the evaluation of f for the reduced system, associated with the Krylov subspace.

In particular, I will discuss some possible approaches in which the Krylov subspace is used for the computation of $\mathrm{sign}(A)p$ for given vectors p. With the evaluation of the matrix *sign* function we have to be extremely careful. A popular approach, based on a Newton iteration, converges fast, but is sensitive for rounding errors, especially when A is ill-conditioned. We will briefly discuss a computational method that was suggested (and analysed) by Bai and Demmel [15]. This approach can also be combined, in principle, with the subspace reduction technique.

Iterative Krylov Methods For Large Linear Systems

Randolph Bank,Michael Holst,Olof Widlund,Jinchao Xu

Iterative Krylov Methods For Large Linear Systems:

Iterative Krylov Methods for Large Linear Systems H. A. van der Vorst,2003-04-17 Computational simulation of scientific phenomena and engineering problems often depends on solving linear systems with a large number of unknowns This book gives insight into the construction of iterative methods for the solution of such systems and helps the reader to select the best solver for a given class of problems The emphasis is on the main ideas and how they have led to efficient solvers such as CG GMRES and BI CGSTAB The author also explains the main concepts behind the construction of preconditioners The reader is encouraged to gain experience by analysing numerous examples that illustrate how best to exploit the methods The book also hints at many open problems and as such it will appeal to established researchers There are many exercises that motivate the material and help students to understand the essential steps in the analysis and construction of algorithms

Krylov Methods for Nonsymmetric Linear Systems Gérard Meurant,Jurjen Duintjer Tebbens,2020-10-02 This book aims to give an encyclopedic overview of the state of the art of Krylov subspace iterative methods for solving nonsymmetric systems of algebraic linear equations and to study their mathematical properties Solving systems of algebraic linear equations is among the most frequent problems in scientific computing it is used in many disciplines such as physics engineering chemistry biology and several others Krylov methods have progressively emerged as the iterative methods with the highest efficiency while being very robust for solving large linear systems they may be expected to remain so independent of progress in modern computer related fields such as parallel and high performance computing The mathematical properties of the methods are described and analyzed along with their behavior in finite precision arithmetic A number of numerical examples demonstrate the properties and the behavior of the described methods Also considered are the methods implementations and coding as Matlab like functions Methods which became popular recently are considered in the general framework of Q OR quasi orthogonal Q MR quasi minimum residual methods This book can be useful for both practitioners and for readers who are more interested in theory Together with a review of the state of the art it presents a number of recent theoretical results of the authors some of them unpublished as well as a few original algorithms Some of the derived formulas might be useful for the design of possible new methods or for future analysis For the more applied user the book gives an up to date overview of the majority of the available Krylov methods for nonsymmetric linear systems including well known convergence properties and as we said above template codes that can serve as the base for more individualized and elaborate implementations **Algorithms for Sparse Linear Systems** Jennifer Scott,Miroslav Tůma,2023-04-29 Large sparse linear systems of equations are ubiquitous in science engineering and beyond This open access monograph focuses on factorization algorithms for solving such systems It presents classical techniques for complete factorizations that are used in sparse direct methods and discusses the computation of approximate direct and inverse factorizations that are key to constructing general purpose algebraic preconditioners for iterative solvers A unified framework is used that emphasizes the

underlying sparsity structures and highlights the importance of understanding sparse direct methods when developing algebraic preconditioners Theoretical results are complemented by sparse matrix algorithm outlines This monograph is aimed at students of applied mathematics and scientific computing as well as computational scientists and software developers who are interested in understanding the theory and algorithms needed to tackle sparse systems It is assumed that the reader has completed a basic course in linear algebra and numerical mathematics Handbook of Linear Algebra, Second Edition Leslie Hogben,2013-11-26 With a substantial amount of new material the Handbook of Linear Algebra Second Edition provides comprehensive coverage of linear algebra concepts applications and computational software packages in an easy to use format It guides you from the very elementary aspects of the subject to the frontiers of current research Along with revisions and updates throughout the second edition of this bestseller includes 20 new chapters New to the Second Edition Separate chapters on Schur complements additional types of canonical forms tensors matrix polynomials matrix equations special types of matrices generalized inverses matrices over finite fields invariant subspaces representations of quivers and spectral sets New chapters on combinatorial matrix theory topics such as tournaments the minimum rank problem and spectral graph theory as well as numerical linear algebra topics including algorithms for structured matrix computations stability of structured matrix computations and nonlinear eigenvalue problems More chapters on applications of linear algebra including epidemiology and quantum error correction New chapter on using the free and open source software system Sage for linear algebra Additional sections in the chapters on sign pattern matrices and applications to geometry Conjectures and open problems in most chapters on advanced topics Highly praised as a valuable resource for anyone who uses linear algebra the first edition covered virtually all aspects of linear algebra and its applications This edition continues to encompass the fundamentals of linear algebra combinatorial and numerical linear algebra and applications of linear algebra to various disciplines while also covering up to date software packages for linear algebra computations

Spectral Methods for Uncertainty Quantification Olivier Le Maitre,Omar M Knio,2010-03-11 This book deals with the application of spectral methods to problems of uncertainty propagation and quanti cation in model based computations It speci cally focuses on computational and algorithmic features of these methods which are most useful in dealing with models based on partial differential equations with special att tion to models arising in simulations of uid ows Implementations are illustrated through applications to elementary problems as well as more elaborate examples selected from the authors interests in incompressible vortex dominated ows and compressible ows at low Mach numbers Spectral stochastic methods are probabilistic in nature and are consequently rooted in the rich mathematical foundation associated with probability and measure spaces Despite the authors fascination with this foundation the discussion only ludes to those theoretical aspects needed to set the stage for subsequent applications The book is authored by practitioners and is primarily intended for researchers or graduate students in computational mathematics physics or uid dynamics The book assumes familiarity with

elementary methods for the numerical solution of time dependent partial differential equations prior experience with spectral me ods is naturally helpful though not essential Full appreciation of elaborate examples in computational uid dynamics CFD would require familiarity with key and in some cases delicate features of the associated numerical methods Besides these shortcomings our aim is to treat algorithmic and computational aspects of spectral stochastic methods with details suf cient to address and reconstruct all but those highly elaborate examples **High Performance Computing for Computational Science -- VECPAR 2010** José M. Laginha M. Palma,Michel Daydé,Osni Marques,Joao Correia Lopes,2011-02-18 This book constitutes the thoroughly refereed post conference proceedings of the 9th International Conference on High Performance Computing for Computational Science VECPAR 2010 held in Berkeley CA USA in June 2010 The 34 revised full papers presented together with five invited contributions were carefully selected during two rounds of reviewing and revision The papers are organized in topical sections on linear algebra and solvers on emerging architectures large scale simulations parallel and distributed computing numerical algorithms **Matrix Analysis and Computations** Zhong-Zhi Bai,Jian-Yu Pan,2021-09-09 This comprehensive book is presented in two parts the first part introduces the basics of matrix analysis necessary for matrix computations and the second part presents representative methods and the corresponding theories in matrix computations Among the key features of the book are the extensive exercises at the end of each chapter Matrix Analysis and Computations provides readers with the matrix theory necessary for matrix computations especially for direct and iterative methods for solving systems of linear equations It includes systematic methods and rigorous theory on matrix splitting iteration methods and Krylov subspace iteration methods as well as current results on preconditioning and iterative methods for solving standard and generalized saddle point linear systems This book can be used as a textbook for graduate students as well as a self study tool and reference for researchers and engineers interested in matrix analysis and matrix computations It is appropriate for courses in numerical analysis numerical optimization data science and approximation theory among other topics **Domain Decomposition Methods in Science and Engineering XX** Randolph Bank,Michael Holst,Olof Widlund,Jinchao Xu,2013-07-03 These are the proceedings of the 20th international conference on domain decomposition methods in science and engineering Domain decomposition methods are iterative methods for solving the often very large linearor nonlinear systems of algebraic equations that arise when various problems in continuum mechanics are discretized using finite elements They are designed for massively parallel computers and take the memory hierarchy of such systems in mind This is essential for approaching peak floating point performance There is an increasingly well developed theory whichis having a direct impact on the development and improvements of these algorithms Numerical Solution of Partial Differential Equations on Parallel Computers Are Magnus Bruaset,Aslak Tveito,2006-03-05 Since the dawn of computing the quest for a better understanding of Nature has been a driving force for technological development Groundbreaking achievements by great scientists have paved the way from the abacus to the supercomputing power of today

When trying to replicate Nature in the computer s silicon test tube there is need for precise and computable process descriptions The scienti c elds of Ma ematics and Physics provide a powerful vehicle for such descriptions in terms of Partial Differential Equations PDEs Formulated as such equations physical laws can become subject to computational and analytical studies In the computational setting the equations can be discreti ed for ef cient solution on a computer leading to valuable tools for simulation of natural and man made processes Numerical so tion of PDE based mathematical models has been an important research topic over centuries and will remain so for centuries to come In the context of computer based simulations the quality of the computed results is directly connected to the model s complexity and the number of data points used for the computations Therefore computational scientists tend to ll even the largest and most powerful computers they can get access to either by increasing the si e of the data sets or by introducing new model terms that make the simulations more realistic or a combination of both Today many important simulation problems can not be solved by one single computer but calls for parallel computing **Distributed and Parallel Systems** Peter Kacsuk,Thomas Fahringer,Zsolt Nemeth,2007-05-03 Distributed and Parallel Systems From Cluster to Grid Computing is an edited volume based on DAPSYS 2006 the 6th Austrian Hungarian Workshop on Distributed and Parallel Systems which is dedicated to all aspects of distributed and parallel computing The workshop was held in conjunction with the 2nd Austrian Grid Symposium in Innsbruck Austria in September 2006 This book is designed for a professional audience composed of practitioners and researchers in industry It is also suitable for advanced level students in computer science

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