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A parallel algorithm of subspace iterations and its implementation on a multiprocessor with ring architecture

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Abstract – A subspace iteration method for solving partial eigenvalue problems is considered. Different algorithms realizing this method are discussed for a computer consisting of several universal processors. An efficient implementation of the method on a multiprocessor computer with ring architecture is suggested. An almost complete utilization of all processors is achieved while the data exchanges between memories of different processors are minimal.

The subspace iteration method (known also as the simultaneous iteration method, the Bauer method, etc.) is widely used. Though lately the Lanzocs method has been rapidly developed the subspace iteration method is not superseded. It is still used for computation of vibrations and stability of structures. The area of its applications is still growing, for instance, it is used for solving problems on criticality of nuclear reactors [3]. The theory of the method (for symmetric eigenvalue problems) is rather well developed [4,5,8] and for one of the algorithms there exists a standard code [9].

In connection with the increasing number of multiprocessor installations it was indicated [2] that subspace iterations evidently allow for a natural 'parallel' implementation. When considering the subject in more detail one can state a problem of choosing the architecture of a multiprocessor computer [1] to minimize the data exchanges between processors. The present paper deals with the solution of this problem.

In Section 1 the partial eigenvalue problem is formulated and the subspace iteration method is described.

Section 2 considers various algorithms implementing the method on a multiprocessor computer without taking into account the type of interprocessor communications.

In Section 3 a scheme of the simultaneous iteration method for a computer with ring architecture is suggested and it is shown that with this scheme an almost complete utilization of all the processors is achieved while the data exchanges between memories of different processors are minimal.

1. SUBSPACE ITERATIONS FOR SOLVING PARTIAL EIGENVALUE PROBLEMS

Let a symmetric positive definite real matrix $A = A^{\mathrm{T}} > 0$ be given. The eigenvectors $u_1, \ldots, u_p$ corresponding to the p largest eigenvalues $\lambda_1 > \ldots > \lambda_p$ of the matrix A can be computed using the subspace iterations

$$U^{n+1} = AU^n, \qquad \dim U^n = p, \qquad n = 0, 1, \ldots \tag{1.1}$$

starting from a given (and almost arbitrary) initial guess U^0. As is known [2,4,5] the subspaces U^n converge

$$U^n \to U = \operatorname{span}\{u_1, \ldots u_p\}, \qquad n \to \infty \tag{1.2}$$

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Numerical Analysis Of Eigenvalue Algorithms Based On Subspace Iterations

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The Shock and Vibration Digest ,1987-07 **Energy Research Abstracts** ,1993 **Domain Decomposition Methods in Science and Engineering XVI** Olof Widlund,David E. Keyes,2007-07-30 Domain decomposition is an active interdisciplinary research area concerned with the development analysis and implementation of coupling and decoupling strategies in mathematical and computational models of natural and engineered systems Since the advent of hierarchical distributed memory computers it has been motivated by considerations of concurrency and locality in a wide variety of large scale problems continuous and discrete Historically it emerged from the analysis of partial differential equations beginning with the work of Schwarz in 1870 The present volume sets forth new contributions in areas of numerical analysis computer science scientific and industrial applications and software development **Core-Chasing Algorithms for the Eigenvalue**

Problem Jared L. Aurentz,Thomas Mach,Leonardo Robol,Raf Vandebril,David S. Watkins,2018-07-06 Eigenvalue computations are ubiquitous in science and engineering John Francis s implicitly shifted QR algorithm has been the method of choice for small to medium sized eigenvalue problems since its invention in 1959 This book presents a new view of this classical algorithm While Francis s original procedure chases bulges the new version chases core transformations which allows the development of fast algorithms for eigenvalue problems with a variety of special structures This also leads to a fast and backward stable algorithm for computing the roots of a polynomial by solving the companion matrix eigenvalue problem The authors received a SIAM Outstanding Paper prize for this work This book will be of interest to researchers in numerical linear algebra and their students **Numerical Methods for Large Eigenvalue Problems** Yousef Saad,2011-05-26 This revised edition discusses numerical methods for computing the eigenvalues and eigenvectors of large sparse matrices It provides an in depth view of the numerical methods that are applicable for solving matrix eigenvalue problems that arise in various engineering and scientific applications Each chapter was updated by shortening or deleting outdated topics adding topics of more recent interest and adapting the Notes and References section Significant changes have been made to Chapters 6 through 8 which describe algorithms and their implementations and now include topics such as the implicit restart techniques the Jacobi Davidson method and automatic multilevel substructuring **Applied Mechanics Reviews** ,2000 *Chinese Journal of Numerical Mathematics and Applications* ,2003 *The Matrix Eigenvalue Problem* David S. Watkins,2007-01-01 An in depth theoretical discussion of the two most important classes of algorithms for solving matrix eigenvalue problems **Lanczos Algorithms for Large Symmetric Eigenvalue Computations Vol. I Theory** Jane K. Cullum,WILLOUGHBY,1985 *Eigenvalue Algorithms for Symmetric Hierarchical Matrices* Thomas Mach,2012 This thesis is on the numerical computation of eigenvalues of symmetric hierarchical matrices The numerical algorithms used for this computation are derivations of the LR Cholesky algorithm the preconditioned inverse iteration and a bisection method based on LDL factorizations The investigation of QR decompositions for H matrices leads to a new QR decomposition It has some properties that are superior to the existing ones which is shown by experiments using the HQR decompositions to build a QR eigenvalue algorithm for H matrices does not progress to a more efficient algorithm than the LR Cholesky algorithm The implementation of the LR Cholesky algorithm for hierarchical matrices together with deflation and shift strategies yields an algorithm that require O n iterations to find all eigenvalues Unfortunately the local ranks of the iterates show a strong growth in the first steps These H fill ins makes the computation expensive so that O n flops and O n storage are required Theorem 4 3 1 explains this behavior and shows that the LR Cholesky algorithm is efficient for the simple structured Hl matrices There is an exact LDLT factorization for Hl matrices and an approximate LDLT factorization for H matrices in linear polylogarithmic complexity This factorizations can be used to compute the inertia of an H matrix With the knowledge of the inertia for arbitrary shifts one can compute an eigenvalue by bisectioning The slicing the spectrum algorithm can compute all

eigenvalues of an Hl matrix in linear polylogarithmic complexity A single eigenvalue can be computed in O k n log 4 n Since the LDLT factorization for general H matrices is only approximative the accuracy of the LDLT slicing algorithm is limited The local ranks of the LDLT factorization for indefinite matrices are generally unknown so that there is no statement on the complexity of the algorithm besides the numerical results in Table 5 7 The preconditioned inverse iteration computes the smallest eigenvalue and the corresponding eigenvector This method is efficient since the number of iterations is independent of the matrix dimension If other eigenvalues than the smallest are searched then preconditioned inverse iteration can not be simply applied to the shifted matrix since positive definiteness is necessary The squared and shifted matrix M mu I is positive definite Inner eigenvalues can be computed by the combination of folded spectrum method and PINVIT Numerical experiments show that the approximate inversion of M mu I is more expensive than the approximate inversion of M so that the computation of the inner eigenvalues is more expensive We compare the different eigenvalue algorithms The preconditioned inverse iteration for hierarchical matrices is better than the LDLT slicing algorithm for the computation of the smallest eigenvalues especially if the inverse is already available The computation of inner eigenvalues with the folded spectrum method and preconditioned inverse iteration is more expensive The LDLT slicing algorithm is competitive to H PINVIT for the computation of inner eigenvalues In the case of large sparse matrices specially tailored algorithms for sparse matrices like the MATLAB function eigs are more efficient If one wants to compute all eigenvalues then the LDLT slicing algorithm seems to be better than the LR Cholesky algorithm If the matrix is small enough to be handled in dense arithmetic and is not an Hl 1 matrix then dense eigensolvers like the LAPACK function dsyev are superior The H PINVIT and the LDLT slicing algorithm require only an almost linear amount of storage They can handle larger matrices than eigenvalue algorithms for dense matrices For Hl matrices of local rank 1 the LDLT slicing algorithm and the LR Cholesky algorithm need almost the same time for the computation of all eigenvalues For large matrices both algorithms are faster than the dense LAPACK function dsyev *Numerical Methods for Eigenvalue Problems* Steffen Börm,Christian Mehl,2012-05-29 Eigenvalues and eigenvectors of matrices and linear operators play an important role when solving problems from structural mechanics and electrodynamics e g by describing the resonance frequencies of systems when investigating the long term behavior of stochastic processes e g by describing invariant probability measures and as a tool for solving more general mathematical problems e g by diagonalizing ordinary differential equations or systems from control theory This textbook presents a number of the most important numerical methods for finding eigenvalues and eigenvectors of matrices The authors discuss the central ideas underlying the different algorithms and introduce the theoretical concepts required to analyze their behavior with the goal to present an easily accessible introduction to the field including rigorous proofs of all important results but not a complete overview of the vast body of research Several programming examples allow the reader to experience the behavior of the different algorithms first hand The book addresses students and lecturers of mathematics

physics and engineering who are interested in the fundamental ideas of modern numerical methods and want to learn how to apply and extend these ideas to solve new problems **International Aerospace Abstracts** ,1998 *Journal of the Engineering Mechanics Division* ,1973 *SIAM Journal on Numerical Analysis* ,2000-03 **Ice Sheets, Sea Level, and the Dynamic Earth** ,2002

Unveiling the Magic of Words: A Overview of "**Numerical Analysis Of Eigenvalue Algorithms Based On Subspace Iterations**"

In some sort of defined by information and interconnectivity, the enchanting power of words has acquired unparalleled significance. Their ability to kindle emotions, provoke contemplation, and ignite transformative change is really awe-inspiring. Enter the realm of "**Numerical Analysis Of Eigenvalue Algorithms Based On Subspace Iterations**," a mesmerizing literary masterpiece penned with a distinguished author, guiding readers on a profound journey to unravel the secrets and potential hidden within every word. In this critique, we shall delve in to the book is central themes, examine its distinctive writing style, and assess its profound affect the souls of its readers.

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Table of Contents Numerical Analysis Of Eigenvalue Algorithms Based On Subspace Iterations

Numerical Analysis Of Eigenvalue Algorithms Based On Subspace Iterations Introduction

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