第三届数值代数及高性能计算研讨会

The Third Workshop on Numerical Algebra and

High Performance Computation

2011 年 3 月 26－27 日

会

议

程

序

主办：香港中文大学数学系

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香港数学协会

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目录

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香港中文大学

日期：2011年3月26－27日

背景与目标

2011年数值代数与高性能计算学术研讨会将于2011年3月26－27日在香港中文大学举行。会议的目的是给内地数值代数学者与港澳数值代数学者提供一个高水平学术交流的平台，以增进交流与合作，加强数值代数在高性能科学与工程计算方面的实践与应用。会议将邀请内地与港澳数值代数领域的著名专家报告他们最近研究成果。

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一般资料

1. **交通：**
   - 凯悦酒店至研讨会会场。早上有专车送至研讨会会场。具体时间见下表。未能乘坐专车的教授敬请乘坐校园巴士(免费)或者步行前往研讨会。从酒店至研讨会会场乘车地点为**港铁大学站**，下车地点为**邵逸夫堂**(第二站)。从研讨会会场返回酒店需要乘坐校园巴士，乘车地点为**大学行政楼**(餐厅对面)，下车地点为**港铁大学站**。

	专车	校园巴士时刻表
3 月 26 日	7:45 酒店大厅集合 7:50 开车	7:45－9:00　每 5 分钟一班 9:00－18:00　每 5～15 分钟一班 18:00－23:00　每 20 分钟一班
3 月 27 日	7:45 酒店大厅集合 7:50 开车	8:40; 9:20 10:00－12:00　每 20 分钟一班 12:40; 13:20; 13:40－22:40　每 20 分钟一班

   - 雅礼宾馆至研讨会会场
     - 步行。需 5 分钟左右。

2. 伙食安排

- 参会教授：组委会在范克廉楼(Benjamin Franklin Centre)免费为参会教授提供会议期间伙食。

	早餐	午餐	晚宴/晚餐
3 月 26 日	8:00－8:25	12:30－14:00	18:30－20:00
3 月 27 日	8:00－8:25	12:30－14:00	18:00－19:30

- 参会学生：参会学生可参加 3 月 26 日晚宴(免费)，地点范克廉楼。其余请自行就餐。

3. 网络链接

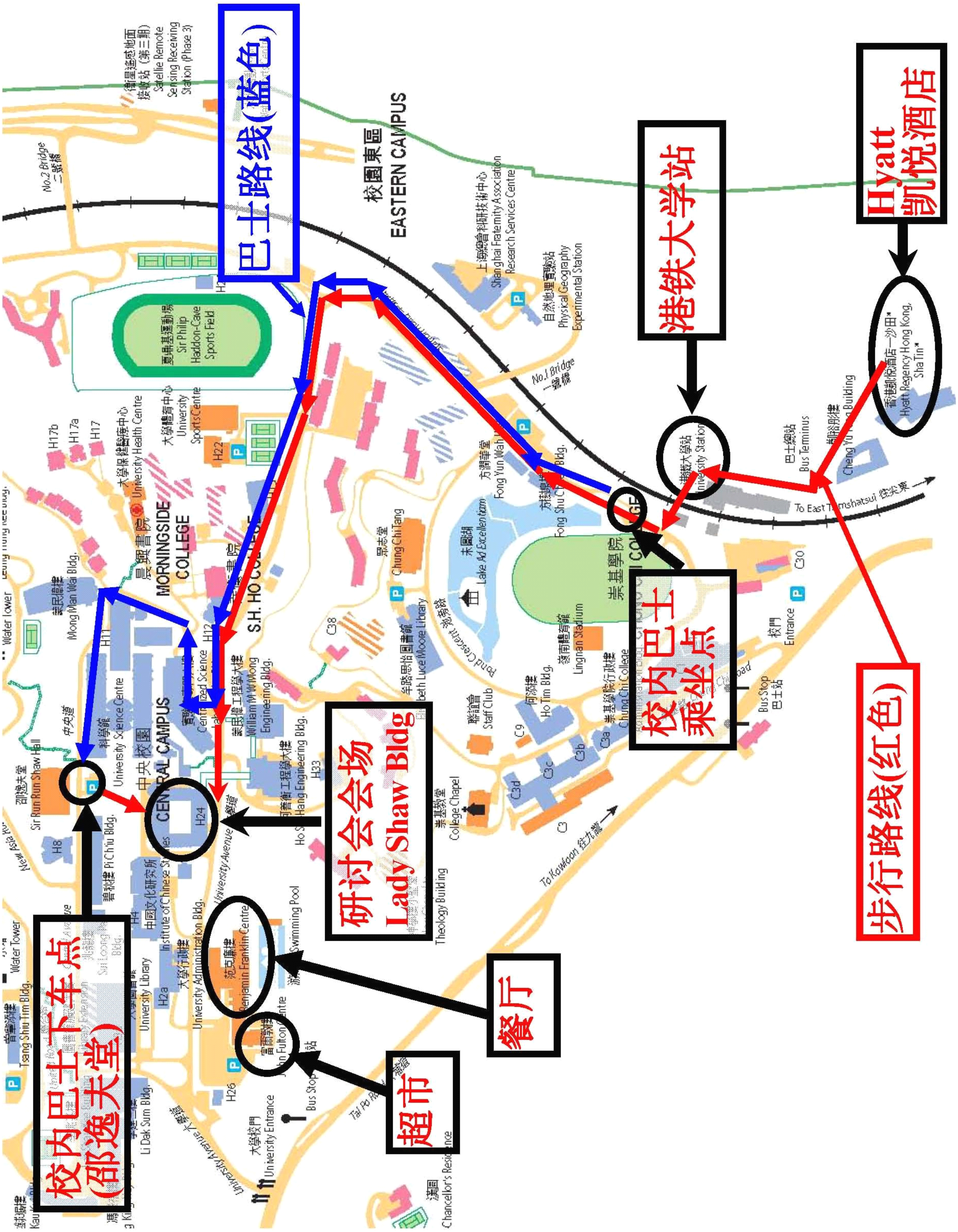
- 无线网络：如需访问无线网络，敬请向工作人员查询网络用户名及密码。
- 有线网络：数学系计算机机房提供有线网络访问服务，机房位于邵逸夫夫人楼(Lady Shaw Building)232B，开放时间为：9:30－12:00，14:00－17:30。机房在开放时间有专人看守，敲门即开。其他时间如需使用网络，敬请向工作人员查询。计算机登录用户名：nahpc3,密码：NAHPC3。星期日办公楼外门已锁，开门密码为：8396。

4. 如需拨打内地电话，可以在 7-11 店或者 OK 店购买香港 "People IDD 至抵傾" 储值卡。该卡拨打香港本地以及内地通话费为 0.25 港币每分钟。

5. 联系人电话：（香港区号 00852）97149017(陈汉夫教授)、67392422(文有为博士)、研究生：68403712（蔡小昊)、97262322（李子豪)、51852936（林达腾)。

地图

一、凯悦酒店



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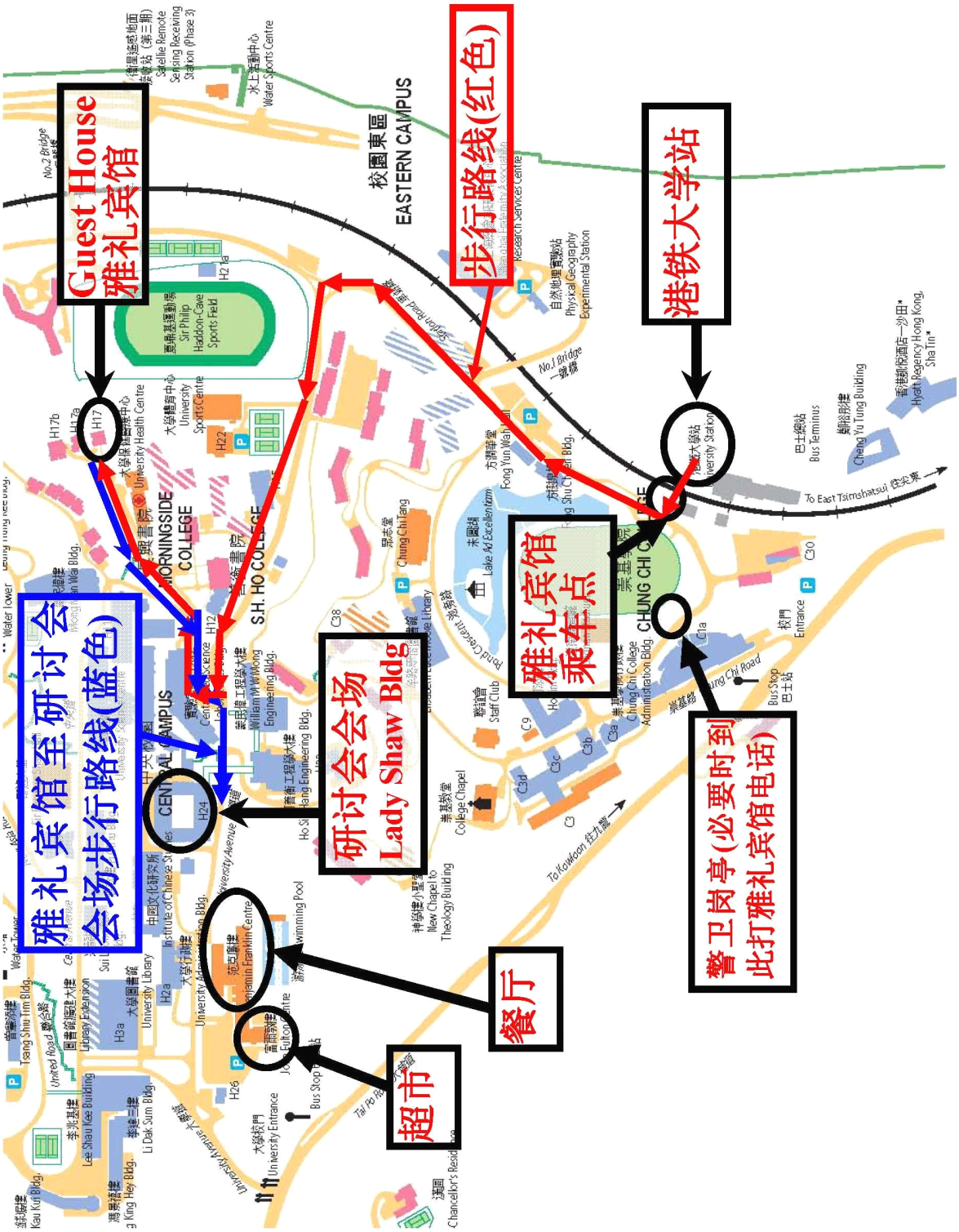

第三届数值代数及高性能计算研讨会日程表

地　点：Lady Shaw Building LT3

3月26日	
8:30－12:30　主持人：吴国宝教授	
8:30－8:45	开幕词
8:45－9:15	石钟慈院士(中国科学院) Finite Element Approximation for Reissener-Mindlin Plates
9:15－9:45	林文伟教授(国立台湾大学) The Nonlinear Matrix Equation $X + X^{\top}X^{-1}A = Q$ and Its Applications in Nano Research
9:45－10:15	刘兴平研究员(北京应用物理与计算数学研究所) 大型稀疏线性代数方程组迭代方法及其应用
10:15－11:00	**拍照、茶点**
11:00－11:30	张振跃教授(浙江大学) Successively Alternate Least Square for Low-rank Matrix Factorization with Bounded Missing Data
11:30－12:00	储德林教授(新加坡国立大学) Generalized Orthogonal LDA for Data Dimensionality Reduction On Unsampled Problems
12:00－12:30	顾传青教授(上海大学) Model Reduction of Large-Scale Dynamical Systems Via Equality Constrained Least Squares
12:30－14:00	**午餐**(Benjamin Franklin Centre)
14:00－18:30　主持人：王仁宏教授	
14:00－14:30	祁力群教授(香港理工大学) Eigenvalues of Nonnegative Tensors
14:30－15:00	于波教授(大连理工大学) Hybrid Divide-and-Conquer Methods for Solving Polynomial Systems
15:00－15:30	孙海卫教授(澳门大学) On the Stability of an Oscillation-free ADI Method in Laser Beam Propagation Computations

15:30－16:00	王丽教授(南京师范大学) Finite Difference Methods for Solving Crack Problems
16:00－16:30	**休息、茶点**
16:30－17:00	卢琳璋教授(厦门大学) A Projection Method and Kronecker Product Preconditioner for Solving Sylvester Tensor Equations
17:00－17:30	安恒斌研究员(北京应用物理与计算数学研究所) Multi-grid Preconditioned Newton-Krylov Method for Solving the 2-D 3-T Energy Equations on Deforming Meshes
17:30－18:00	谷同祥研究员(北京应用物理与计算数学研究所) 二维粒子输运方程离散解的预条件 Krylov 子空间迭代方法
18:00－18:30	黄玉梅教授(兰州大学) Block-Triangular Preconditioners for Systems Arising from Edge Preserving Image Restoration
18:30－20:00	**晚宴**(Benjamin Franklin Centre)
20:00－21:30	张贴报告
3月27日	
8:30－12:00　**主持人：陈汉夫教授**	
8:30－9:00	蒋尔雄教授(上海大学) The Inverse Eigenvalue Problems for Jacobi Matrices
9:00－9:30	苏仰锋教授(复旦大学) Applications of Linearization of Rational Eigenvalue Problems
9:30－10:00	黎稳教授(华南师范大学) Some Residual Bounds for Approximate Eigenvalues and Approximate Eigenspaces
10:00－10:30	**休息、茶点**
10:30－11:00	张绍良教授(日本名古屋大学) An Arnoldi(M,W,G) Method for Generalized Eigenvalue Problems
11:00－11:30	高卫国教授(复旦大学) On Two-grid Discretization Schemes for Eigenvalue Problem

11:30－12:00	白正简教授(厦门大学) Nonnegative Inverse Eigenvalue Problems with Partial Eigendata
12:00－12:30	陈小君教授(香港理工大学) $l_2 - l_p$ Nonconvex Minimization Theory and Applications
12:30－14:00	**午餐**（Benjamin Franklin Centre）
14:00－15:30　主持人：程纬琪教授	
14:00－14:30	杨俊锋教授(南京大学) A Proximal Point Algorithm for Log-determinant Optimization with Group Lasso Regularization
14:30－15:00	袁晓明教授(香港浸会大学) Linearized Alternating Direction Method for Constrained Linear Least-squares Problem
15:00－15:30	**休息、茶点**
15:30－16:00	魏益民教授(复旦大学) Convergence of General Nonstationary Iterative Methods for Solving Singular Linear Equations
16:00—16:30	殷俊锋教授(同济大学) Restarted Full Orthogonalization Method with Deflation Technique for Shifted Linear Systems
16:30－17:00	林福荣教授(汕头大学) A Residual Correction Scheme for Linear Systems with Band Plus Near Low Rank Coefficient Matrix
17:00－	自由安排参观香港活动
18:00	**晚餐**（Benjamin Franklin Centre）

口头报告摘要

Finite Element Approximation for Reissener-Mindlin Plates

Zhong-Ci Shi

Institute of Computational Mathematics, Chinese Academy of Sciences

The Reissner-Mindlin plate model is one of the most commonly used models of a moderate-thick to thin elastic plate. However, a direct finite element approximation usually yields very poor results, which is referred to LOCKING phenomenon. In the past two decades, many efforts have been devoted to the design of locking free finite elements to resolve this model, most of these work focus on triangular or rectangular elements, the latter may be extended to parallelograms, but very few on quadrilaterals. In this talk we will give an overview of the recent development of low order quadrilateral elements and present some new results.

The Inverse Eigenvalue Problems for Jacobi matrices

Erxiong Jiang

Department of Mathematics, Shanghai University, Shanghai

The inverse eigenvalue problems for Jacobi matrices are very interesting subject both in theory and practice.This report introduce six typical inverse eigenvalue problems for Jacobi matrices. They are problem I,II,III,IV,problem (K) and periodic problem.

Eigenvalues of Nonnegative Tensors

Liqun Qi

Department of Applied Mathematics The Hong Kong Polytechnic University

The eigenvalue problem of nonnegative tensors has applications in multi-linear pagerank, spectral hypergraph theory and higher-order Markov chains, etc. The eigenvalue problem of general or symmetric tensors is in general NP-hard. On the other hand, recently, it was discovered that the largest eigenvalue problem of a nonnegative tensor has linearly convergent algorithms. This research topic attracted much attention. In the world, now there are at least ten research teams at USA, France, Italy, Australia, Mainland China and Hong Kong, working on this topic. On December 24, 2010, a Workshop on Eigenvalues of Nonnegative Tensors was held at PolyU. We now review the progress on this topic.

Multigrid Preconditioned Newton-Krylov Method for Solving the 2-D 3-T Energy Equations on Deforming Meshes

Heng-Bin An

Institute of Applied Physics and Computational Mathematics

The 2-D 3-T energy equations is a kind of strongly nonlinear systems that is used to describe the energy diffusion and exchanging between electron and photon or ion. In multiphysics simulations, the energy diffusion and exchanging process is coupled with some other physical processes. Consequently, the 3-T energy equations should be discretized on the deforming meshes which is moved with dynamics. Because the energy diffusion and swapping coefficients are strongly nonlinear dependent on the temperature, and some physical parameters are discontinuous across the materials interfaces, it is a challenge to solve the discretized nonlinear algebraic equations in multiple physics applications. In this report, a Newton-Krylov method is used to solve the discretized 3-T energy equations, and four kinds of preconditioners are constructed, and an algebraic multigrid method is used to solve the preconditioning system.

Nonnegative Inverse Eigenvalue Problems with Partial Eigendata

Zheng-Jian Bai, Stefano Serra-Capizzano, and Zhi Zhao
Xiamen University

In this paper, we consider the inverse problem of constructing an n-by-n real nonnegative matrix A from prescribed partial eigendata. We reformulate the inverse problem as a monotone complementarity problem and then propose a nonsmooth Newton-type method for solving the nonsmooth equation related to the monotone complementarity problem. Under some very mild assumptions, we show that our method has simultaneously a global and quadratic convergence. We also specialize our method to the symmetric nonnegative inverse problem, and to the cases of a prescribed lower bound and of prescribed entries. Numerical tests demonstrate the efficiency of the proposed method and support our theoretical findings.

*** The research of the first author was partially supported by the Natural Science Foundation of Fujian Province of China for Distinguished Young Scholars (No. 2010J06002) and Internationalization Grant of U. Insubria 2008, 2009.

$l_2 - l_p$ Nonconvex Minimization Theory and Applications

Xiaojun Chen
The Hong Kong Polytechnic University

The $l_2 - l_p$ minimization is nonsmooth and nonconvex in which the objective function is the sum of a data-fitting term in l_2 norm and a regularization term in l_p norm ($0 < p < 1$). In [1], we establish lower bounds for the absolute value of nonzero entries in every local optimal solution of the model, which can be used to identify zero entries precisely in any numerical solution. Therefore, we have developed a lower bound theorem to classify zero and nonzero entries in its every local solution. These lower bounds clearly show the relationship between the sparsity of the solution and the choice of the regularization parameter and norm.

Extensive numerical experiments have shown that the iteratively reweighted l_1 minimization algorithm (IRL1) is a very efficient method for solving $l_2 - l_p$ minimization. However no convergence results have been given for the IRL1. In [3] we first give a global convergence theorem of the IRL1. We prove that any sequence generated by the IRL1 converges to a stationary point of the $l_2 - l_p$ minimization problem. Moreover, the stationary point is a global minimizer in certain domain and the convergence rate is approximately linear under certain conditions.

In [4], we study $l_2 - l_p$ minimization with box constraints for image restoration. We present a positive constant θ and show that the difference between each pixel and its four adjacent neighbors is either 0 or larger than θ in the recovered image. Our theoretical results show that the solution of this imaging restoration problem is composed of constant regions surrounded by closed contours and neat edges. Numerical examples are presented to validate the theoretical results and show that the proposed model can recover image restoration results very well.

References

1. X.Chen, F. Xu and Y. Ye, Lower bound theory of nonzero entries in solutions of $l_2 - l_p$ minimization, SIAM J. Scientific Computing, 32(2010), 2832-2852.

2. X. Chen and W. Zhou, Smoothing nonlinear conjugate gradient method for image restoration using nonsmooth nonconvex minimization, SIAM J. Imaging Sciences, 3(2010), 765-790.

3. X. Chen and W. Zhou, Convergence of reweighted l_1 minimization algorithms and unique solution of truncated l_p minimization, April, 2010.

4. X. Chen, M. Ng and C. Zhang, Nonconvex l_p-regularization and box constrained model for image restoration, December 2010.

Generalized Orthogonal LDA for Data Dimensionality Reduction On Unsampled Problems

Delin Chu
National University of Singapore

Dimensionality reduction has become an ubiquitous preprocessing step in many applications. Linear discriminant analysis (LDA) has been known to be one of the most optimal dimensionality reduction methods for classification. However, a main disadvantage of LDA is that the so-called "total scatter matrix" must be nonsingular. But, in many applications, the scatter matrices can be singular since the data points are from a very high-dimensional space and thus usually the number of the data samples is smaller than the data dimension. This is known as the undersampled problem. Many generalized LDA methods have been proposed in the past to overcome this singularity problem. There is a commonality for these generalized LDA methods, that is, they compute the optimal linear transformations by computing some eigen-decompositions and involving some matrix inversions. However, the eigen-decomposition is computationally expensive, and the involvement of matrix inverses may lead to that the methods are not numerically stable if the associated matrices are ill-conditioned. Hence, many existing LDA methods have high computational cost and potentially numerical instability problems.

In this talk we introduce a new orthogonal LDA method (OLDA) on the undersampled problem. The main features of the new OLDA method include: (i) the optimal transformation matrix is obtained easily by only orthogonal transformations without computing any eigen-decomposition and matrix inverse, and consequently, the new OLDA method is inverse-free and numerically reliable; (ii) the new OLDA method is implemented by using several QR factorizations and is a fast one. The effectiveness of new method is illustrated by some real-world data sets.

On Two-grid Discretization Schemes for Eigenvalue Problem

Weiguo Gao
Fudan University

Multigrid methods have been used to solve eigenvalue problems with kinetic and potential terms from physical sciences. In this talk, we compare different schemes for two-grid eigenvalue problem from numerical linear algebra viewpoint. More precisely, we first explain why the interpolation of coarse grid solution is not a good guess on fine grids in general. Then we utilize the simple local recovery technique on small region, which solves a set of local Poisson problems on fine grids. With this scheme, solving a problem on fine grids is reduced to solving a coarse eigenvalue problem plus solving a set of local fine grid linear systems. It is proved theoretically that optimal precision will be obtained for free particle problem. Although it is cheap to perform, unfortunately, we verify that local recovery does not give very accurate solution for the problems with general potential term unless the region is big enough. Instead we show that solving a shift-invert linear system always achieves optimal precision. Moreover, an inexact scheme can be developed to reduce the computational cost.

Model Reduction of Large-Scale Dynamical Systems Via Equality Constrained Least Squares

Yu'e An and *Chuanqing Gu*
Dept. of Math. Shanghai Univ., Shanghai, 200444, China

In this paper, we present a new model reduction method of large scale dynamical systems, which belongs to SVD-Krylov based method. It is a two-sided projection where one side reflects the Krylov part, and the other side reflects the SVD(observability gramian) part. The reduced model matches the first $r+i$ Markov parameters of the full order model, where r is the order of reduced system, and i is a nonnegative integer such that $1 \leq i < r$. The reduced system minimizes a weighted $\mathscr{H}_2$ error. By the definition of shift operator, the proposed approximation is also obtained by solving

an equality constrained least squares problem. Moreover, the method is generalized for moment matching at arbitrary interpolation points. Several numerical examples verify the effectiveness of the approach.

Key words: Model reduction; Equality constrained least squares; Shift operator; Hankel matrix; Interpolation

二维粒子输运方程离散解的预条件Krylov子空间迭代方法

谷同祥†，曹艳华§，刘兴平†，李茂生†
† 北京应用物理与计算数学研究所，计算物理实验室
§ 华北电力大学数理系

二维粒子输运方程经离散纵标(S_N) 方法离散后，常用的迭代求解方法是源迭代方法，它本质上是一种Richardsion迭代法。因此，其收敛速度非常慢，特别当强散射或光学厚时。本文基于代数方法，形成两种离散求解方案：其一是在S_N离散后形成大型稀疏矩阵，使用基于问题的预条件子结合Krylov子空间方法迭代求解；其二是通过数学推导，写出矩阵向量乘积的计算公式，从而实现了无矩阵的预条件Krylov子空间求解方式。数值试验比较了新方法与源迭代方法的性能，对于源迭代难于收敛的情形，新方法的加速可达一个量级。

Block-Triangular Preconditioners for Systems Arising from Edge-preserving Image Restoration

Yumei Huang
Lanzhou University

Signal and image restoration problems are often solved by minimizing a cost function consisting of an ℓ_2 data-fidelity term and a regularization term. We consider a class of convex and edge-preserving regularization functions. In specific, half-quadratic regularization as a fixed point iteration method is usually employed to solve this problem. The main aim of this paper is to solve the above-described signal and image restoration problems with the half-quadratic regularization technique by making use of the Newton method. At each iteration of the Newton method, the Newton equation is a structured system of linear equations of a symmetric positive definite coefficient matrix, and may be efficiently solved by the preconditioned conjugate gradient method accelerated with the modified block SSOR preconditioner. Our experimental results show that this approach is more feasible and effective than the half-quadratic regularization approach.

Some Residual Bounds for Approximate Eigenvalues and Approximate Eigenspaces

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In this talk we discuss approximate eigenvalues and approximate eigenspaces for the generalized Rayleigh quotient, and present some residual bounds. Our bounds will improve the corresponding ones.

A Residual Correction Scheme for Linear Systems with Band Plus Near Low Rank Coefficient Matrix

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Many problems in mathematics and engineering lead to linear systems with coefficient matrix of the form

$$A = B + L,$$

where B is a band matrix or other structured matrix, and L can be approximated accurately by certain low rank matrices. In this talk, we first present a residual correction scheme for the linear system $(B+L)\mathbf{x}=\mathbf{b}$. We then apply the residual correction scheme to several problems, including one-dimensional and two-dimensional integral equations of the second kind with smooth kernel functions, and a partial integro-differential equation from option pricing. Numerical results are shown to illustrate the efficient of the scheme.

The Nonlinear Matrix Equation $X + X^\top X^{-1}A = Q$ and Its Applications in Nano Research

Wenwei Lin
National Taiwan University

The matrix equation $X+A^\top X^{-1}A=Q$ arises in Green's function calculations in nano research, where A is a real square matrix and Q is a real symmetric matrix dependent on a parameter and is usually indefinite. In practice one is mainly interested in those values of the parameter for which the matrix equation has no stabilizing solutions. The solution of interest in this case is a special weakly stabilizing complex symmetric solution X_*, which is the limit of the unique stabilizing solution X_η of the perturbed equation $X+A^\top X^{-1}A=Q+i\eta I$, as $\eta\to 0^+$. It has been shown that a doubling algorithm can be used to compute X_η efficiently even for very small values of η, thus providing good approximations to X_*. It has been observed by nano scientists that a modified fixed-point method can sometimes be quite useful, particularly for computing X_η for many different values of the parameter. We provide a rigorous analysis of this modified fixed-point method and its variant, and of their generalizations. We also show that the imaginary part X_I of the matrix X_* is positive semi-definite and determine the rank of X_I in terms of the number of unimodular eigenvalues of the quadratic pencil $\lambda^2 A^\top - \lambda Q + A$. Finally we present a new structure-preserving algorithm that is applied directly on the equation $X+A^\top X^{-1}A=Q$. In doing so, we work with real arithmetic most of the time.

大型稀疏线性代数方程组迭代方法及其应用

刘兴平，杭旭登，谷同祥
北京应用物理与计算数学研究所，计算物理实验室

本报告介绍了我们研究的并行BICRSTAB迭代算法、并行GPBiCG(m,l)迭代算法、多色序混合迭代算法以及预处理技术等理论研究成果。同时还介绍了这些理论研究成果分别在ICF数值模拟中求解二维三温方程形成的大型稀疏线性代数方程组和在油藏数值模拟中求解化学驱三维多相流渗流方程形成的大型稀疏线性代数方程组的应用情况。

A Projection Method and Kronecker Product Preconditioner for Solving Sylvester Tensor Equations

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In this talk, we consider the preconditioned iterative solvers for Sylvester tensor equation

$$\mathcal{X}\times_1 A^{(1)} + \mathcal{X}\times_2 A^{(2)} + \cdots + \mathcal{X}\times_N A^{(N)} = \mathcal{D},$$

where known matrices $A^{(n)}\in\mathcal{R}^{I_n\times I_n}(n=1,\ 2,\ \cdots,\ N)$, tensor $\mathcal{D}\in\mathcal{R}^{I_1\times I_2\times\cdots\times I_N}$, and unknown tensor $\mathcal{X}\in\mathcal{R}^{I_1\times I_2\times\cdots\times I_N}$.

By fully exploiting the structure of the tensor equation, we propose a tensor format projection method, which needs less flops and storage than the standard projection method. The structure of

the coefficient matrices of Sylvester tensor equation is used to design the nearest Kronecker product (NKP) preconditioner, which is easy to construct and is able to accelerate the convergence of the iterative solver. Numerical experiments are presented to show good performance of the approaches.

Keywords: Sylvester tensor equation; Schur decomposition; projection method; nearest Kronecker product (NKP); preconditioning

Applications of Linearization of Rational Eigenvalue Problems

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Linearizations technique proposed recently by us are applied to solve rational egenvalue problems from several applications, including eigenvibration analysis of a string with a load of mass attached by an elastic spring, mechanical vibrations of fluid-solid structures, electronic band structure calculation for photonic crystal, dissipative acoustic problem, and electro-magnetic wave in waveguide-loaded cavity. These applications show that the linearization technique is very efficient for practical problems.

This is a joint work with Zhaojun Bai from University of California at Davis, and Xin Huang from Fudan University.

On the Stability of an Oscillation-free ADI method in Laser Beam Propagation Computations

Hai-wei Sun
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In this paper, we study the highly oscillatory paraxial Helmholtz equations in laser optics applications. Since the wave number involved can be extremely large in optical applications, the complex envelope is highly oscillatory. Consequently, higher efficiencies in solution computations for the above equation are difficult to achieve as mesh steps cannot be unrealistically small. Although for the spectrum, Gaussian beam methods and integral transformations may possess certain advantages in the situation, the main challenge pertains in balancing the algorithmic simplicity and accuracy. This motivates a recent study of the eikonal transformation based numerical methods which can change the higher oscillatory equation to be real and non-oscillatory even when the wave number is extremely large. In this paper, we consider to employ an oscillation-free alternative-direction-implicit (ADI) finite difference method for solving the resulting equation. The mesh steps anticipated for solving them need not to be particularly small. This ADI method is shown to be asymptotically stable when wave numbers anticipated are large. This is a joint work with Qin Sheng who is from Baylor University.

Finite Difference Methods for Solving Crack Problems

Li Wang
Nanjing Normal University

Finite difference schemes based on asymptotic analysis and the augmented immersed interface method are proposed for potential problems with an inclusion whose characteristic width is much smaller than the characteristic length in one and two dimensions. We call such a problem as a crack problem for simplicity. In the proposed method, The jump conditions for the crack problems are derived. The coefficient matrix of the finite difference equations is still an M-matrix. Numerical experiments are presented.

Convergence of General Nonstationary Iterative Methods for Solving Singular Linear Equations

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In this talk, we analyze the convergence of the general nonstationary iterative methods for solving consistent singular linear equations (in particular, singular Hermitian positive semidefinite linear systems), and we discuss relations of general stationary results and ours.We utilize the quotient convergence to prove the convergence of the two-stage iterative algorithms for solving the consistent singular Hermitian positive semidefinite linear equations.

A Proximal Point Algorithm for Log-determinant Optimization with Group Lasso Regularization

Junfeng Yang
Nanjing University

We propose a practical proximal point algorithm for solving large scale log-determinant optimization problem with group Lasso regularization and linear equality constraints. At each iteration, as it is difficult to update the primal variables directly, we solve the dual problem by a Newton-CG method, and update the primal variables by an explicit formula based on the computed dual variables. Theoretically, we show that the generalized Jacobian matrix of the nonlinear systems is definite provided that the constraint nondegeneracy conditions hold for the primal problem. We present numerical results to demonstrate that the proposed algorithm is efficient, especially when high accuracy is required.

Restarted Full Orthogonalization Method with Deflation Technique for Shifted Linear Systems

Junfeng Yin
Tongji University

In this paper, we study shifted restated full orthogonalization method with deflation for simultaneously solving a number of shifted systems of linear equations. Theoretical analysis shows that if the residuals of all shifted systems of linear equations are collinear with each other, the new residuals are still collinear by applying the deflation technique. Hence, our approach can solve the shifted systems simultaneously based on the same Krylov subspace. Numerical experiments show that the deflation technique can improve the convergence performance of shifted restarted FOM.

Hybrid Divide-and-Conquer Methods for Solving Polynomial Systems

Bo Yu
School of Mathematical Sciences, Dalian University of Technology,

In this talk, a brief introduction of some hybrid divide-and-conquer methods for solving polynomial systems will be given. At first, for polynomial systems difrived from mixed trigonometric polynomial systems, a hybrid homotopy and its improved symmetric version will be introduced, and the sketch of a hybrid divide-and-conquer method for this special class of polynomial systems will be formulated. Then, a framework of a general-purpose hybrid divide-and-conquer method for solving deficient polynomial systems will be given. Some numerical results will also be given to show the efficiency of the proposed algorithm.

Linearized Alternating Direction Method for Constrained Linear Least-squares Problem

Xiaoming Yuan
Department of Mathematics, Hong Kong Baptist University

In this paper, we apply the alternating direction method (ADM) to solve a constrained linear least-squares problem where the objective function is a sum of two least-squares terms and the constraints are box constraints. Using ADM, we decompose the original problem into two easier least-squares subproblems at each iteration. To speed up the inner iteration, we linearize the subproblems whenever their closed-form solutions do not exist. We prove the convergence of the resulting algorithm and apply it to solve some image deblurring problems. We show the efficiency of our algorithm by comparing it with Newton-type methods.

An Arnoldi(M,W,G) Method for Generalized Eigenvalue Problems

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The Arnoldi method was proposed to compute a few eigenpairs of large-scale generalized eigenvalue problems. For the iterative computation of eigenpairs, this method generates the basis of a subspace by solving linear systems. This leads to considerable computation time for the large-scale problems. In this talk, to reduce the computation time, we propose an Arnoldi(M,W,G) method based on the Arnoldi method.

Successively Alternate Least Square for Low-rank Matrix Factorization with Bounded Missing Data

Keke Zhao and *Zheyue Zhang*
Zhejian University

The problem of low-rank matrix factorization with missing data has attracted many significant attention in the fields related to computer vision. The previous model mainly minimizes the total errors of the recovered low-rank matrix on observed entries. It may produce an optimal solution with less physical meaning. This paper gives a theoretical analysis of the sensitivities of the original model and proposes a modified constrained model and iterative methods for solving the constrained problem. We show that solutions of original model can be arbitrarily far from each others. Two kinds of sufficient conditions of this catastrophic phenomenon are given. In general case, we also give a low bound of error between an ϵ-optimal solution that is practically obtained in computation and a theoretically optimal solution. A constrained model on missing entries is considered for this missing data problem. We propose a two-step projection method for solving the constrained problem. We also modify the method by a successive alternate technique. The proposed algorithm, named as SALS, is easy to implement, as well as converges very fast even for a large matrix. Numerical experiments on simulation data and real examples are given to illuminate the algorithm behaviors of SALS.

张贴报告摘要

Regularized Least-squares Approximations on the Sphere Using Spherical Designs

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We consider polynomial approximation on the unit sphere $\mathbb{S}^2 = \{(x, y, z) \in \mathbb{R}^3 : x^2+y^2+z^2 = 1\}$ by a class of regularized discrete least squares methods, with novel choices for the regularizing operator and the point sets of the discretisation. We allow different kinds of rotationally invariant regularization operators, including the zero operator (in which case the approximations includes interpolation, quasi-interpolation and hyperinterpolation [3]); powers of the negative Laplace-Beltrami operator (which can be suitable when there are data errors); and regularizers that yield filtered polynomial approximations, which (even for exact data) exhibit improved uniform approximation compared to the unregularized case. As node sets we use spherical t-designs [1], which are point sets on the sphere which when used as equal-weight quadrature rules integrate all spherical polynomials up to degree t exactly. For an approximating polynomial of degree L and $t \geq 2L$ there is no linear algebra problem to be solved, and the approximation in some cases recovers known polynomial approximation schemes, including interpolation, generalized hyperinterpolation and filtered hyperinterpolation [3]. For $t \in [L, 2L)$, where the linear system needs to be solved numerically, we define well conditioned spherical t-designs by minimizing the condition number of the sum of the Gram matrix and regularization matrix over the set of spherical t-designs. Moreover, we propose an efficient preconditioning method [4] to solve the discrete least squares problems. Finally, we give numerical examples to illustrate the theoretical results, and show that well chosen regularizers and well conditioned spherical t-designs can provide good polynomial approximation on the sphere, with or without the presence of data errors.

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Additive And Multiplicative Perturbation Bounds for the Moore C Penrsore Inverse

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In this paper, we obtain the additive and multiplicative perturbation bounds for the Moore-Penrose inverse under the unitarily invariant norm and the Q- norm, which improve the corresponding ones in [P.Wedin, Perturbation theory for pseudo-inverses,BIT 13(1973)217-232].

Perturbation Bounds for the Periodic Schur Decomposition

Xiaoshan Chen
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This paper is devoted to the perturbation analysis for periodic regular matrix pairs. We present perturbation bounds for the periodic Schur decomposition of periodic regular matrix pairs with distinct eigenvalues, which extend the main result of Sun (*SIAM J. Matrix Anal. Appl.* 16:1328ÍC1340, 1995). The results are illustrated by a numerical example.

A Quasi-Minimal Residual Variant of the IDR(s) for Nonsymmetric Linear Systems

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We propose a quasi-minimal residual variant of the IDR(s) method [*Sonneveld and van Gijzen, SIAM J. Sci. Comput.,* **31***(2008), pp. 1035-1062*] for solving linear systems $A\mathbf{x} = \mathbf{b}$, where $\mathbf{b} \in \mathbb{R}^{\mathbf{n}}$ and A is a real sparse and nonsymmetric matrix. Our method is called QMRIDR(s) for short. Compared with IDR(s), QMRIDR(s) can converge more smoothly without increasing the number of matrix-vector products. Numerical experiments are reported to show the performance of our method.

Inexact Shift-Invert Scheme for Two-grid Eigenvalue Problem

Qun Gu
Fudan Univeristy

This work devotes to develop a novel scheme of two-grid method in solving eigenvalue problems with finite element discretization.

Shift-and-invert strategy is introduced as a corrector on fine grids. Solving the fine-grid eigenvalue problem is no harder than a coarse eigenvalue problem plus a global linear system problem. We find that when the tolerance of the linear system is set to be a positive constant that is less than one but not close to one, the resulting solution of two-grid method will be optimal. Moreover, if the linear solver is specified as a so-called B-MINRES method, with the help of the property of orthogonality, the tolerance is allowed be relaxed to $1-O(h)$, while the solution still achieve optimal precision. However, in B-MINRES algorithm, an explicit inversion of mass matrix B is required to form Krylov subspace. As a result, we develop an inexact version of B-MINRES to obviate explicit inversion and prove that the resulting solution of inexact version is close to the exact version.

Kronecker Product Approximations for Image Restoration with Whole-sample Symmetric Boundary Conditions

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Reflexive boundary conditions (BCs) assume that the array values outside the viewable region are given by a symmetry of the array values inside. The reflection guarantees the continuity of the image. In fact, there are usually two choices for the symmetry: symmetry around the meshpoint and symmetry around the midpoint. The first is called whole-sample symmetry in signal and image processing, the second is half-sample. Many researchers have developed some fast algorithms for the problems of image restoration with the half-sample symmetric BCs over the years. However, little attention has been given to the whole-sample symmetric BCs. In this paper, we consider the use of the whole-sample symmetric boundary conditions in image restoration. The blurring matrices constructed from the point spread functions (PSFs) for the BCs have block Toeplitz-plus-PseudoHankel

with Toeplitz-plus-PseudoHankel blocks structures. Recently, regardless of symmetric properties of the PSFs, a technique of Kronecker product approximations was successfully applied to restore images with the zero BCs, half-sample symmetric BCs and anti-reflexive BCs, respectively. All these results extend quite naturally to the whole-sample symmetric BCs, since the resulting matrices have similar structures. It is interesting to note that when the size of the true PSF is small, the computational complexity of the algorithm obtained for the Kronecker product approximation of the resulting matrix in this paper is very small. It is clear that in this case all calculations in the algorithm are implemented only at the upper left corner submatrices of the big matrices. Finally, detailed experimental results reporting the performance of the proposed algorithm are presented.

The Inverse Positivity of Perturbed Tridiagonal M-matrices

Jie Huang, Ting-Zhu Huang

A well-known property of an M-matrix M is that the inverse is element-wise non-negative, which we write as $M^{-1} \geq 0$. We consider element-wise perturbations of non-symmetric tridiagonal M-matrices and obtain sufficient bounds on the perturbations so that the non-negative inverse persists. In particular, these sufficient bounds are shown to be the actual maximum allowable perturbations when the second diagonals (elements $(l, l+2)$ and $(l, l-2)$) of M are perturbed.

A Novel Integration Method for Weak Singularity Arising in Two-Dimensional Scattering Problems

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In this paper, we introduce a novel mechanical quadrature method for an efficient solution of weakly singular integral equations arising in two-dimensional electromagnetic scattering problems. This approach is based on and adapted from the recently proposed mechanical quadrature methods in [Extrapolation algorithms for solving mixed boundary integral equations of the Helmholtz equation by mechanical quadrature methods, *SIAM J. Sci. Comput.*, vol. 31, 4115ÍC4129, 2009]. We report experiments for solving TM-polarized induced currents and scattered fields to show its superiority to the classical method of moments when accuracy is a concern. Moreover, additional numerical experiments made with an extrapolation algorithm suggest that the accuracy of the present method can be further improved dramatically by means of the extrapolation algorithm to some extent.

Solving Large-Scale Algebraic Riccati Equations by Doubling

Tiexiang Li, Eric King-wah Chu, Wen-Wei Lin

We consider the solution of large-scale algebraic Riccati equations with (numerically) low-ranked solutions. For the discrete-time case, the structure-preserving doubling algorithm will be adapted for the sparsity and the low-ranked structures in the algebraic Riccati equation. For the continuous-time case, the algebraic Riccati equation will be

rst treated with the Cayley transform before doubling is applied. With n being the dimension of the algebraic Riccati equations, the resulting algorithms are of a feasible $O(n)$ complexity. Some numerical results will be presented. As an example, a DARE of dimension $n = 79841$, with 3.19 billion variables in the solution X, was solved using MATLAB on a MacBook Pro to machine accuracy within 1,100 seconds.

A New Regularization Method for Fredholm Integral Equations of the First Kind

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Many problems in engineering fields such as image processing lead to Fredholm integral equations of the first kind. These equations are difficult to solve numerically due to their ill-posedness. This paper presents a new regularization method which is based on weighted H^1 seminorm. We use the Newton method to solve the corresponding minimization problem. Details of numerical implementation are given. Several numerical examples, including one dimensional and two dimensional cases, are shown to illustrate the efficiency of the proposed approach. Numerical results show that the proposed regularization method can effectively distinguish between edges and smooth regions.

Keywords: Fredholm integral equation of the first kind, piecewise continuous solution, weighted H^1 seminorm.

A Refined Safeguarded RQI Method for Symmetric Tridiagonal Matrix Eigenproblems

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For symmetric tridiagonal eigenproblems, RQI has locally cubic convergence rate, however, it is difficult to predict to which eigenvalue it converges. Bisection method only has linear convergence rate and is often used to compute one or all eigenvalues in a specific interval. In this work, we propose a hybrid method, named Refined Safeguarded RQI (RSRQI) method, Furthermore; a refinement process is proposed to remedy the possible misconvergence. Numerical experiments show that RSRQI outperforms the bisection method in LAPACK in speed by 20

This is a joint with Yangfeng Su.

Shift-invert Lanczos method for the symmetric positive semidefinite Toeplitz matrix exponential

Hong-Kui Pang and Hai-wei Sun
Department of Mathematics, University of Macau, Macao, China

The Lanczos method with shift-invert technique is exploited to approximate the symmetric positive semidefinite Toeplitz matrix exponential. The complexity is lowered by the Gohberg Semencul formula and the fast Fourier transform. Application to the numerical solution of an integral equation is studied. Numerical experiments are carried out to demonstrate the effectiveness of the proposed method.

求解约束最小二乘的数值比较－－牛顿法与交替方向法

陶敏
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本文采用线性化交替方向法求解一类带约束的最小二乘问题，此类问题起源采用Tikhonov正则化方法求解病态的图像恢复问题。本文的贡献在于，充分利用目标函数及约束条件可分离的性质，提出采用交替方向法来求，由于在求解子问题时，存在子问题没有显式解，所以提出采用线性化松弛的手段简化子问题的求解。本文提出的线性化方法具有全局收敛性。文中大量的数值试验表明我们的方法优于一些经典的二阶方法，比如Reduced Newton method, BB Newton method. 同时，数值结果也证明了在最小二乘模型中引入约束可以提高恢复图像的质量。

Refined Jacobi-Davidson Type Method for a Right Definite Two-Parameter Eigenvalue Problem

Zhongming Teng
Xiamen University

In their paper of M. E. Hochstenbach and B. Plestenjak considered that the refined method is not suitable for two-parameter eigenvalue problems because of high costs for computation, poor convergence of refined Ritz vectors and incapacity for computing more than one eigenvalue. In this paper, we show that it is not the case. We propose an efficient refined Jacobi-Davidson type method for a right definite two-parameter eigenvalue problem and show that refined Ritz vectors have better convergence than Ritz vectors and (refined) Ritz values is convergent.

Conforming Rectangular Mixed Finite Elements For Elasticity

Yana Wang
Chinese Academy of Sciences

We present a new family of rectangular mixed finite elements for the stress-displacement system of the plane elasticity problem. Based on the theory of mixed finite element methods, we prove that they are stable and obtain error estimates for both the stress field and the displacement field. Using the finite element spaces in this family, an exact sequence is established as a discrete version of the elasticity complex in two dimensions. And the relationship between this discrete version and the original one is shown in a commuting diagram.

The Finest Level Acceleration of Multilevel Aggregation for Markov Chains

Chun Wen，Ting-Zhu Huang，De-An Wu，Liang Li

In this paper, we consider a class of new accelerated multilevel aggregation methods by the use of two polynomial-type vector extrapolation methods: one is the reduced rank extrapolation (RRE) method, and the other is the generalization of quadratic extrapolation (GQE) method. We show how to combine the multilevel aggregation methods with RRE and GQE algorithms on the finest level for speeding up the numerical computation of the stationary probability vector for an irreducible Markov chain. Numerical experiments on three typical Markov chain problems are used to illustrate the efficiency of our accelerated multilevel aggregation methods.

On Adaptively Accelerated Arnoldi Method for Computing PageRank

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A generalized refined Arnoldi method based on the weighted inner product is presented for computing PageRank. The properties of the generalized refined Arnoldi method are studied. In order to speed up the convergence performance for computing PageRank, we propose to change the weights adaptively where the weights are calculated based on the current residual according to the current approximate PageRank vector. Numerical results show that the proposed Arnoldi method converges faster than existing methods, in particular when the damping factor is large.

Robust Continuation Methods for Tracing Solution Curves of Parameterized Equations

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The continuation methods are efficient methods to trace solution paths of nonlinear systems with parameters, which are common in many fields of science and engineering. Existing continuation methods are unstable for some complicated cases in practice, such as the case that solution curves are closed to each other or the case that the curve turns acutely at some point. In this paper, a robust and simple corrector strategy— sphere corrector is presented. Using this new strategy, combining various predictor strategies and various iterative solution methods with local quadratic or superlinear convergence rates, robust continuation procedures are given. When the predictor steplength is no more than the so-called granularity of solution curves, our procedure of tracing solution curve can avoid "path-jumping" and can follow the whole solution curve, and hence solve the problems that can not be solved by other continuation methods.

Key words: Parameterized equation; Homotopy method; Continuation method.

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Novel Delayed Size-Reduction Technique for Low-Complexity LLL-Aided MIMO Detection

Wen Zhang, Yimin Wei, and Sanzheng Qiao
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The LLL algorithm is a famous lattice basis reduction method which has been widely used in wireless communications. In time critical applications, such as multiinput multioutput (MIMO) systems, the speed of the LLL algorithm is crucial. In this paper, we present the first complexity analysis of the LLL-like algorithms for real lattice basis. After that, we propose a novel technique, called delayed size-reduction, to speed up the LLL algorithm. The speed-up is achieved by delaying some operations and consolidating procedures, consequently, reducing the number of conditional instructions and eliminating redundant operations. Theoretical analysis shows that the new algorithm can reduce the complexity by one order as compared to the original LLL algorithm. Simulation results reveal that the LLL algorithm with delayed size-reduction can significantly outperform the conventional one without sacrificing the quality of the results.

泛函微分与泛函方程单支θ方法的稳定性

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对于非线性泛函微分和泛函方程数值方法的稳定性研究，将单支θ方法用于求解一类非线性泛函微分与泛函方程，结果表明：在问题真解稳定（或渐近稳定）的条件下，单支θ方法当$1/2 \leq \theta \leq 1$时是数值稳定，$1/2 < \theta < 1$时是渐近稳定的，数值试验验证了所获理论的正确性。

Low-rank Models with Proleptic Regularization for Collaborative Filtering

Keke Zhao
Zhejian University

Low-rank Matrix factorization with missing data is known as an effective tool for Collaborative Filtering since it generates high quality rating predictions for recommender systems. One of the major problem of regularized matrix factorization model is over-fitting phenomenon. This paper

proposes a proleptic regularization model to reduce the risk of over-fitting and improve the approximation accuracy. The proleptic regularization uses a pre-estimation for a preindicated testing set to regularize to the unknown rating values in the CF problem. We give two similar models that are suitable for solving by alternate least square method and stochastic gradient descent algorithm, respectively. We also give a fast implementation of the alternative least square algorithm which is very suitable for parallel computing. The proposed algorithms works well. In the performance of our algorithms on the 10M MovieLens data, the proposed algorithms improve the best results; the accuracy can be increased by above 2 to 8 for variant tested data scales.

Vector Extrapolation Based Landweber Method for Ill-posed Problems

Xi-Le Zhao, Ting-Zhu Huang, ZongBen Xu, Xiao-Guang Lv

Landweber method is one of the classical iterative methods for solving linear discrete ill-posed problems which arise from inverse problems. However Landweber method generally has a slow convergence behavior. In this paper, we present the vector extrapolation based Landweber method which has a fast and stable convergence behavior. Moreover, a restarted version of the vector extrapolation based Landweber method is proposed for practical considerations. Numerical results are given to illustrate the performance of the vector extrapolation based Landweber method.

Modulus-based Successive Overrelaxation Method for Pricing American Options

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We consider the modulus-based successive overrelaxation method for the linear complementarity problems from the discretization of Black-Scholes American options pricing model. The sufficient condition for the convergence of proposed methods is given. Numerical experiment confirm the theoretical analysis, and further show that our approach is superior to the classical projected successive overrelaxation method.

Keywords. American option pricing, Black-Scholes model, linear complementarity problems, modulus-based successive overrelaxation, projected successive overrelaxation

3 月 25 日晚上观光香港路线(自费)

- 路线 1：尖沙咀海傍—“幻彩咏香江”激光秀—尖沙咀购物

5:10PM 居住在**雅礼宾馆**的参会者在宾馆楼下集合, 一同前往港铁大学站 A 出口.
5:20PM 居住在**凯悦酒店**的参会者在酒店大厅集合, 一同前往港铁大学站 A 出口.
5:30PM 在港铁大学站 A 出口集合，乘坐火车经红磡转车到尖东地铁站
6:15PM 沿尖沙咀海傍(星光大道，特色建筑如尖沙咀钟楼、半岛酒店、1881 Heritage / 前香港水警总部)参观
7:15PM 在尖沙咀区用餐
8:00PM 餐后前往观看“幻彩咏香江”激光秀
8:15PM 看秀毕，自由活动时间，可在尖沙咀区购物（如香港最大面积的购物中心海港 城）或欣赏香港夜景（欲先回大学者可乘坐地铁折返）
9:45PM 有需要者可到约定地点集合，随带队学生到尖沙咀站乘坐地铁回大学
10:15PM 到达大学火车站，行程结束

- 路线 2：天星小轮—山顶缆车—凌霄阁

5:10PM 居住在雅礼宾馆的参会者在宾馆楼下集合, 一同前往港铁大学站 A 出口.
5:20PM 居住在凯悦酒店的参会者在酒店大厅集合, 一同前往港铁大学站 A 出口.
5:30PM 在港铁大学站 A 出口集合，乘坐火车经红磡转车到尖东地铁站
6:15PM 步行前往尖沙咀天星码头，乘坐天星小轮（1898 年 5 月 1 日至今）横渡维多利 亚海港，观看维港两岸景色
6:35PM 在中环天星码头下船，乘坐公交 15C 路到花园道山顶缆车站，乘坐著名山顶缆 车（始建于 1888 年）上太平山， 在山顶广场用餐
8:00PM 餐后登上凌霄阁观景台，观看香港夜景及“幻彩咏香江”激光秀
8:30PM 游览毕，坐山顶缆车下山
9:00PM 从山下缆车站步行前往金钟地铁站（需时 15 分钟），乘坐地铁经旺角转车，经九龙塘转车回大学
10:15PM 到达大学火车站，行程结束

注意事项：

- 全程费用自理，其中“幻彩咏香江”激光秀免费。
  - 晚餐：平均每人港币 30—50 元
  - 山顶缆车来回套票（含凌霄阁观景台）：每人港币 56 元
- 建议集合前自行到大学地铁站客务中心购买香港八达通卡（适用于大部分的公交, 快餐点及便利店，但是在 3 个月内退还需交 7 元手续费）
- 尖沙咀海傍（路线 1）为观看“幻彩咏香江”激光秀的较佳地点（正面）

- 3 月 25 日天气预测：14 到 18 摄氏度，短暂时间有阳光
- 海傍及山顶风势较大，请自备御寒衣物
- 参观网页
  - 海港城（超级大型商场）：http://www.harbourcity.com.hk/?gb
  - “幻彩咏香江”激光秀：http://www.tourism.gov.hk/symphony/scindex.html
  - 山顶（缆车，山顶广场，凌霄阁）：http://www.thepeak.com.hk/sc/home.asp

联系人（香港区号：＋852）：

蔡小昊（68403712）
李子豪（97262322）

3 月 27 日晚上自由活动香港购物点推荐

旺角：
前往方法：从港铁大学站乘坐火车经九龙塘转车到旺角地铁站 D3 或 E2 出口
女人街：服装、化妆品、摆设等女士用品
波鞋街：运动鞋
西洋菜南街：潮流服饰、电子产品、小吃
郎豪坊商场：大型商场
地图：见附页
庙街：

前往方法：从港铁大学站乘坐火车经九龙塘转车到油麻地地铁站 C 出口
庙街北段：大排档，吃喝为主
庙街南段：服装、手工艺品、茶具、玉器、古董、廉价电子产品
地图：见附页
注：
3 月 27 日天气预测：15 到 18 摄氏度，多云


郎豪坊商场
西洋菜南街
波鞋街
女人街
旺角
Mong Kok
亞皆老街
Argyle St
朗豪坊商場
Langham Place
Shopping Mall
朗豪酒店
Langham
Place Hotel
奶路臣街
Nelson St
Shantung St
Soy St
鼓油街
登打士街
Dundas St
Nathan Rd
彌敦道
上海街
Shanghai St
Tung Choi St
Fa Yuen St
Sai Yee St
洗衣街花園
Sai Yee
Street Garden
麥花臣遊樂場
Macpherson
Playground
廣華醫院
Kwong Wah
Hospital
Waterloo Rd
Portland St
Reclamation St
Hong Lok St
Kam Lam St
Kam Fong St
Ferry St
渡船街
W Kowloon Corridor
西九龍走廊
Hamilton St
咸美頓街
Yin Chong St
煙廠街
Kwong Wa St


油麻地站C出口
廟街（北段）
廟街（南段）
Shek Lung St
Man Ming Ln
Temple St
Tung Kun St
Wing Sing Ln
Public Square St
Battery St
Kansu St
Pak Hoi St
Saigon St
Ning Po St
Woosung St
Reclamation St
Parkes St
Nathan Rd
Gascoigne Rd
加士居道
Yau Ma Tei Telephone Exchange
King's Park
Observatory Meteorological Station
Yau Ma Tei Catholic Primary School
Cinematheque Broadway
Prosperous Garden Block 5
Yau Ma Tei Police Station
Tin Hau Temple
Kowloon Government Offices
Chak Fung House
Clifton Tower
Newman College
The Regalia Block 5
King's Park Tennis Court
Queen Elizabeth Hospital
Pui Ching Education Centre
Methodist School
Queen Elizabeth Hospital School Of General Nursing
Labour Tribunal
Hang Shing Bldg
Tai Koon Mansion
Kim Tak Bldg
Place 18
Saigon Street Playground
King's Park Playground
Red Cross Blood Transfusion Centre
Ymca Centenary