Recent Advances in Scientific Computing and Matrix Analysis

Editors: Xiao-Qing Jin, Hai-Wei Sun & Seak-Weng Vong

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Dedicated to the 30th Anniversary of

University of Macau

(1981–2011)

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Preface

An international workshop on scientific computing and matrix analysis took place at University of Macau from 28th to 30th of December 2009. It was organized by the Department of Mathematics, University of Macau, for the 20th anniversary of the **T**eam **O**n **T**oeplitz **S**ystems (TOTS). The TOTS was born in 1989 in Hong Kong. In that year, Dr. Raymond H. Chan published three important papers on iterative Toeplitz solvers in SIAM journals and had his first graduate student Xiao-qing Jin. Raymond's iterative algorithm is based on the conjugate gradient method together with circulant matrices as preconditioners. He proved in his first paper in 1989 that the complexity of the algorithm is only $O(n \log n)$ where n is the size of the Toeplitz system. The techniques and ideas developed there have now become a standard tool in the trade where most papers adopt and follow. For his contributions in iterative Toeplitz solvers and their applications, Raymond was awarded the Leslie Fox Prize in 1989, the Feng Kang Prize in Scientific Computing in 1997, and the Morningside Silver Medal of Mathematics in 1998.

Since 1989, iterative Toeplitz solvers have become a new research area in numerical linear algebra. With twenty years passed, the TOTS has produced several academic generations and obtained great academic achievements. The main theme of this workshop is the latest development in *matrix computations and applications* made by the TOTS and the papers involved in this proceedings cover this theme. There are sixteen invited speakers from USA, Canada, Singapore, Hong Kong, Macao, and mainland China. Twelve of them are the TOTS members. The following is the list of invited speakers:

Prof. Zhong-ci Shi of Chinese Academy of Sciences, Beijing, China.

Prof. Raymond H. Chan of Chinese University of Hong Kong, Hong Kong.

Prof. Zheng-jian Bai of Xiamen University, Xiamen, China.

Prof. Wai-ki Ching of University of Hong Kong, Hong Kong.

Dr. Yu-mei Huang of Lanzhou University, Lanzhou, China.

Dr. Li-ping Jing of Beijing Jiaotong University, Beijing, China.

Prof. Wen Li of South China Normal University, Guangzhou, China.

Dr. Hai-yong Liao of Hong Kong Baptist University, Hong Kong.

Prof. Fu-rong Lin of Shantou University, Shantou, China.

Prof. San-zheng Qiao of McMaster University, Canada.

Dr. Chi-pan Tam of Hong Kong Baptist University, Hong Kong.

Prof. Yi-min Wei of Fudan University, Shanghai, China.

Dr. You-wei Wen of South China Agricultural University, Guangzhou, China.

Prof. Man-chung Yeung of University of Wyoming, USA.

Dr. Andy M. Yip of National University of Singapore, Singapore.

Dr. Shu-qin Zhang of Fudan University, Shanghai, China.

There are eleven chapters (papers) in this proceedings. The main contents of chapters are described briefly as follows.

A Ulm-like method is proposed for solving inverse eigenvalue problems with distinct given eigenvalues in Chapter 1. The Ulm-like method avoids solving the Jacobian equations used in Newton-like methods and is shown to be quadratically convergent in the root sense. **Z. J. Bai** and X. Q. Jin give a numerical example to show that the Ulm-like method is better than the inexact Newton-like method in terms of convergence neighborhoods.

It has been proved that for any $n \times n$ complex matrices X and Y,

$$\|XY - YX\|_F \leq \sqrt{2}\|X\|_F\|Y\|_F, \qquad (*)$$

where $\|\cdot\|_F$ denotes the Frobenius norm. A characterization of those pairs of matrices that satisfy $(*)$ has also been found. Recently, K. Audenaert has given a new proof of the inequality by introducing a matrix version of variance. In Chapter 2, based on his proof, C. M. Cheng, K. S. Fong, and I. K. Luk give another proof of the equality of $(*)$.

W. K. Ching and D. M. Zhu give a brief review in Chapter 3 on some recent models and results in high-dimensional Markov chain models for categorical data sequences. Categorical data sequences occur in many areas including bioinformatics, operations research, data mining, and financial data modeling, etc. The construction of mathematical models for categorical data sequences is important in the sense that it can help in the discovery of rules, testing hypothesis, and making effective predictions. Ching and Zhu introduce a number of high-dimensional Markov chain models with applications. Efficient estimation methods for the model parameters are also discussed.

In Chapter 4, Y. N. Law, H. K. Lee, C. Q. Liu, and **A. M. Yip** propose a variant of the Mumford-Shah model for the segmentation of overlapping semi-transparent objects with additive intensity value. Unlike standard segmentation models, it does not only determine distinct objects in the image, but also recover possibly multiple membership of the pixels. To accomplish this, *a priori* knowledge about the smoothness of the objects is taken into account in the model. To solve the optimization problem involving geometric quantities efficiently, they apply a multi-phase level set method. Segmentation results on synthetic and real images validate the good performance of their model.

Total variation based methods are popular for image restoration. One typical problem in this kind of method is how to select the regularization parameters. The common approach is try-and-error. In the literature there are several regularization parameter selection methods for Tikhonov regularization problems. In Chapter 5, **H. Y. Liao** and M. K. Ng study the regularization parameter problems in total variation based image deblurring problem. Within the alternating minimization framework, they exploit the generalized cross-validation technique to select the regularization parameter in each iteration. Liao and Ng also extend the idea to blind deconvolution problem. The experimental results are given to demonstrate the performance of the proposed methods.

F. T. Luk and **S. Z. Qiao** present a matrix interpretation of the LLL algorithm for lattice basis reduction in Chapter 6.

A nonconvex nonsmooth regularization has advantages over a convex regularization for restoring images with neat edges. However, its practical interest used to be limited by the difficulty of the computational stage which requires a nonconvex nonsmooth minimization. In Chapter 7, M. Nikolova, M. K. Ng, and **C. P. Tam** study a fast nonconvex nonsmooth minimization method for image restoration and reconstruction. The main aim is to develop a fast minimization algorithm to solve the nonconvex nonsmooth minimization problem. The experimental results show that the effectiveness and efficiency of the proposed method.

Given a row stochastic matrix P of size n, G. Wu examines the relationship between the eigenvalues of P and those of some augmented matrices with respect to P in Chapter 8. Applications of the results to Google's PageRank problem are also discussed.

Chapter 9 considers numerical solution methods for Wiener-Hopf equations of the second kind defined on $[0, \infty)$:

$$y(t) + \int_0^\infty k(t-s)y(s)\mathrm{d}s = g(t), \qquad 0 \le t < \infty.$$

Y. Xuan and **F. R. Lin** first combine the well-known Clenshaw-Curtis quadrature with a rational variable transformation to get a Clenshaw-Curtis-rational (CCR) quadrature rule, which is suitable for integrals on semi-infinite intervals. They then apply the CCR quadrature to Wiener-Hopf equations. The reduction of singularities in Wiener-Hopf equations is also discussed. Numerical examples are given to illustrate the efficiency of the CCR quadrature.

Krylov subspace methods are popular iterative methods to solve large sparse linear systems in the real-world computations due to their cheap memory requirement and computational cost. In Chapter 10, **M. C. Yeung** discusses the solution of singular systems. He shows that the consistency of a singular linear system is not a sufficient condition for a Krylov subspace method to successfully find a solution of the system. The choice of initial guess is a crucial step. If the initial guess is properly chosen, a Krylov method almost surely converges to find a solution from the viewpoint of probability, otherwise a Krylov subspace method surely diverges.

For solving the integer least squares problems arising in many engineering applications, the LLL algorithm is widely used as a preconditioner. But the way how the LLL algorithm works was seldom understood by practitioners, until Luk and Tracy first described the behavior of the algorithm in 2008, and they also derived a new numerical implementation of the LLL algorithm. Luk and Qiao then compare the original and the new LLL algorithms in the cases of overflow and underflow. In Chapter 11, Q. F. Yu, **S. Z. Qiao**, and **Y. M. Wei** look into the difference when the LLL algorithms are applied to the integer least squares problems.

The success of the workshop should be credited to the enthusiastic participation of the attendees. Special thanks for a fund to workshop are addressed to University of Macau. The hospitality of the local organizers and helpers is greatly appreciated. The editors would like to thank all who contributed to this proceedings of the workshop. We wish that the proceedings may provide some inspiration and shed new light on recent research in matrix computations and applications. The publication of the proceedings is supported by the research grant UL020/08-Y3/MAT/JXQ01/FST from University of Macau.

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