The Southern Ontario Numerical Analysis Day (SONAD) is an annual, one-day conference that brings together researchers (faculty, PDFs, visitors) and graduate students working in broad areas of numerical analysis and scientific computing at Ontario universities.

The program this year includes lectures by two distinguished scientists: Tony Chan (UCLA) and Michael Overton (Courant Institute), nine contributed talks, and a poster session.

The financial support from the Fields Institute, Toronto, the Faculty of Engineering, McMaster University, and MITACS is greatly acknowledged.

We wish all participants an enjoyable and fruitful meeting.

Ned Nedialkov
Tamás Terlaky
Jiming Peng

Program

8:30 – 9:15	Breakfast
9:15 – 9:20	Opening
9:20 – 9:30	Welcome by Dr. Mo Elbestawi, Dean of Engineering
9:30 – 10:30	Tony Chan, *A Fast Algorithm for Variational Level Set Image Segmentation*, p. 3
10:30 – 11:00	Break
11:00 – 11:20	Sammy Huen, *Non-Uniform Adaptive Meshing for One-Asset Problems in Finance*, p. 6
11:20 – 11:40	Andreas Grau, *Convertible Bonds with Call Notice Periods*, p. 5
11:40 – 12:00	Kit-Sun Ng, *Spline Collocation on L- and T-shaped Regions*, p. 8
12:00 – 13:10	Lunch
13:10 – 13:30	Nick Kevlahan, *An Adaptive Wavelet Collocation Method for Fluid-Structure Interaction*, p. 7
13:30 – 13:50	Xiaofang Ma, *Computation of the Probability Density Function and the Cumulative Distribution Function of the Generalized Gamma Variance Model*, p. 7
13:50 – 14:10	Shirook M. Ali, *An Efficient Numerical Technique for Gradient Computation with Full Wave Solvers*, p. 5
14:10 – 14:30	Break
14:30 – 14:50	Nezam Mahdavi-Amiri, *Solving Diophantine Linear Equations and Rank-one Perturbed Systems by the ABS Methods*, p. 8
14:50 – 15:10	Maziar Salahi, *The Complexity of Self-Regular Proximity Based Infeasible IPMs*, p. 9
15:10 – 15:30	Samir Hamdi, *Exact Solutions of the Generalized Equal Width Wave Equation*, p. 6
15:30 – 16:00	Break
16:00 – 17:00	Michael Overton, *Measuring and Optimizing Stability of Matrices*, p. 4
17:00 – 17:05	Closing
17:05 – 19:00	Poster Session and Reception
	Xiaorang Li, *XLAB – An Interpreted Programming Language for Numerical Computing*, p. 10
	Xiaohang Zhu, *Implementing the New Self-Regular Proximity Based IPMs*, p. 10

Plenary Talks

A Fast Algorithm for Variational Level Set Image Segmentation

Tony Chan
Department of Mathematics
UCLA

I'll first give an overview of a family of variational image segmentation models based on using level set representation of segment boundaries that L. Vese and I have developed over the last few years. The distinctive feature is use of regional information without using edge detection explicitly. The methodology can handle scalar and multi-valued images, multiple level sets, and logical combinations of information from different channels. In the 2nd part of the talk, I'll present a fast computational algorithm for computing the solution of these variational segmentation models. Instead of the typical PDE-based gradient descent algorithms, the new algorithm is optimization-based and make use of the objective function directly, without the need for any gradient information. The new algorithm speeds up the traditional algorithms dramatically. For 2-phase images, we prove that the algorithm finds the correct segmentation with only one sweep over the pixels of the image, regardless of the ordering of the pixels or the initial level set.

The second part of the talk is joint work with my PhD student Bing Song.

Biography Tony F. Chan received both his B.S. (Engineering) and M.S. (Aeronautics) degrees from the California Institute of Technology in 1973, and his Ph.D. degree in computer science from Stanford University in 1978.

He was an Assistant and then Associate Professor of computer science at Yale University from 1979-1986, when he was lured to UCLA. He served as the Chair of the UCLA Mathematics Department from 1997-2000, until he became Director of the, newly established Institute for Pure and Applied Mathematics (IPAM), one of only 3 NSF-funded national math institutes at that time, which he helped bring to UCLA. He became Dean of the Division of Physical Sciences in July 2001.

As Dean of the Division of Physical Sciences, he oversees 6 departments, several research institutes, over 200 ladder faculty, 1700 undergraduates, and 700 graduate students. The division brings in over $60M in annual research awards. His responsibilities include policy, planning, budget, faculty recruitment, retention and promotion, education and research programs, and fund raising.

Dr. Chan has been an active member of the Society of Industrial and Applied Math and the American Math Society. He served on the SIAM Council, the editorial board of SIAM Review and the SIAM Committee on Human Rights. Currently, he serves on the SIAM Committee on Science Policy and the AMS Editorial Board Committee. He also serves on the editorial boards of the SIAM Journal of Scientific Computing, Numerische Matematik, the Asian Journal of Math, and Numerical Algorithms. He was a co-chair of the Organizing Committee of the July 2000 National SIAM Meeting held in Puerto Rico.

Dean Chan has served on a number of national and professional panels, including the NSF Math and Physical Sciences Advisory Committee, the AMS Committee on Committees, the University Space Research Association (USRA) Science Council for Applied Mathematics and Computer Science, the Lawrence Livermore National Laboratorys Computation Directorate Advisory Committee, the NSFs Division of Mathematical Science Committee of Visitors.

Some of his many honors include: Chairing the Search Committee for the NSF Director of the Division of Mathematical Sciences (2002) and Chairing the Local Organizing Committee for the AMS Mathematical Challenges of the 21st Century Conference held in August 2000 at UCLA. He has served as the Plenary speaker at the Joint Mathematics Meeting held in San Diego, in January 2002; the International Congress of Chinese Mathematicians in held in Taipei, in December 2001; and the SIAM National Meeting held in San Diego, in July 1989. His latest honor is the Distinguished Visiting Lectureship at the United College Chinese University of Hong Kong in November 2002.

Dean Chan's general research interest is interdisciplinary mathematics. Specific current projects include differential equation based image processing and computer vision, multiscale computational methods, optimizational and algebraic multigrid methods for VLSI circuit layout and algorithms on advanced architecture parallel computers.

Measuring and Optimizing Stability of Matrices

Michael Overton
Courant Institute of Mathematical Sciences
New York University

A matrix is stable if its spectral abscissa (maximum real part of its eigenvalues) is negative. The spectral abscissa models only asymptotic behavior of associated dynamical systems, so more practical stability measures include the pseudospectral abscissa (maximum real part of the pseudospectrum) and the distance to instability (minimum norm perturbation required to make a stable matrix unstable). Matrices often arise in applications as parameter dependent, a classic example being A(K) = A0 + BKC, the static output feedback model in control. We formulate two optimization problems over a parameterized matrix family: minimization of the pseudospectral abscissa and maximization of the distance to instability, and present a new algorithm that approximates local optimizers. One of our numerical examples is a difficult stabilization problem from the control literature: a model of a Boeing 767 at a flutter condition.

Joint work with James V. Burke, University of Washington, Seattle, WA and Adrian S. Lewis, Simon Fraser University, Burnaby, BC, Canada

Biography Michael L. Overton received his BSc from UBC in 1974, along with the Governor General's Gold Medal for Arts and Sciences. He received the MS and PhD degrees in Computer Science from Stanford University. He is currently Professor of Computer Science and Mathematics at the Courant Institute of Mathematical Sciences, New York University. Michael Overton is an elected member of the Board of Trustees of SIAM (Society for Industrial and Applied Mathematics) and has also served on the SIAM Council. He is a member of the Council of FoCM (Foundations of Computational Mathematics) and of the Board of Directors of the Canadian Mathematical Society. He serves on the editorial boards of SIAM Journal on Optimization (for which he was Editor-in-Chief from 1995-1999), SIAM Journal on Matrix Analysis and Applications, the IMA Journal on Numerical Analysis, and SIAM Review. His research interests are at the interface of optimization and linear algebra, especially nonsmooth optimization problems involving eigenvalues, with applications to many different subjects including robust control, structural analysis, combinatorial optimization and convex analysis. He is author of "Numerical Computing with IEEE Floating Point Arithmetic" (SIAM, 2001).

Contributed Talks

An Efficient Numerical Technique for Gradient Computation with Full Wave Solvers

Shirook M. Ali and Natalia K. Nikolova

Department of Electrical and Computer Engineering
McMaster University

Efficient optimization methods are those exploiting not only the values of the cost function but also its gradients and even its Hessian matrix. This information becomes harder to achieve when it comes to full wave electromagnetic (EM) solvers since they are numerically complicated solvers to begin with. Therefore, in commercial software, the solver is treated as a black box and the gradients are (usually) evaluated by repeated analyses of the response for the independent design parameters. Such a process can be prohibitively expensive, as the number of design parameters becomes larger. Here, we present a technique that provides the designer with the gradients of the cost function with respect to all the design parameters through a single full wave simulation of the solver in addition to the original simulation. Our technique employs an adjoint-based technique to design sensitivity analysis (DSA) applied to the frequency domain transmission line method (FDTLM). The technique uses the solution of the nominal problem in the calculation of the gradients after a perturbation takes place. Thus, no re-meshing is required during the optimization process. On the other hand, when finite differences (FDs) are used, the optimizer treats the perturbed structure as a new structure. Accordingly, a new full wave simulation is carried out for each perturbation of every single design parameter. The presented technique offers significant savings in memory and CPU time. It is easy to implement and can be, in general, applied to any full wave EM solver based on fixed structured girds.

Convertible Bonds with Call Notice Periods

Andreas Grau

School of Computer Science
University of Waterloo

In practice, convertible bonds can often be called only if notice is given to the holders. Most methods for valuing convertible bonds assume that the bond is continuously callable. In this paper, we develop an accurate PDE method for valuing convertible bonds with a finite notice period. Example computations are presented which illustrate the effect of varying notice periods. The results are compared with a recently published approximation method.

Exact Solutions of the Generalized Equal Width Wave Equation

S. Hamdi [a], W. H. Enright [a], W. E. Schiesser [b] and J. J. Gottlieb [c]

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Lehigh University

[c] Institute for Aerospace Studies
University of Toronto

The equal width wave (EW) equation is a model partial differential equation for the simulation of one-dimensional wave propagation in nonlinear media with dispersion processes. The EW-Burgers equation models the propagation of nonlinear and dispersive waves with certain dissipative effects. In this work, we derive exact solitary wave solutions for the general form of the EW equation and the generalized EW-Burgers equation with nonlinear terms of any order. We also derive analytical expressions of three invariants of motion for solitary wave solutions of the generalized EW equation. The new solutions are illustrate with several examples and animations that elucidate salient features of the propagation of solitary waves and undular bores.

Non-Uniform Adaptive Meshing for One-Asset Problems in Finance

Sammy Huen

School of Computer Science
University of Waterloo

We investigate applying adaptive meshing methods to the problem of valuing one asset derivative contracts numerically by solving the Black-Scholes PDE. Traditionally, this is solved by designing a static non-uniform mesh that is used at every time step in the numerical method. Static meshes have two difficulties: design and applicability. It may be difficult to design a mesh that is applicable for every time step.

We develop a non-uniform mesh generator that allows a mesh to grow, shrink, and move based on mesh equidistribution, refinement, and derefinement. We extend the mesh generator to be adaptable to a smooth solution by controlling the interpolation error of the solution and portfolio profiles. We also develop a method for adapting a mesh to a non-smooth solution.

We apply our adaptive meshing stategies on three derivative option contracts: vanilla, digital, and discrete barrier. We compare the error distributions produced by adaptive meshing with those produced by static meshing. We observe a reduction in the maximum error of the solution and portfolio profile for each type of option contract. Overall, we demonstrate that adaptive meshing can be more efficient in controlling the error in the solution and portfolio profiles.

An Adaptive Wavelet Collocation Method for Fluid-Structure Interaction

N. Kevlahan
Department of Mathematics and Statistics
McMaster University

O. Vasilyev
Department of Mechanical Engineering
University of Colorado at Boulder

This talk describes a new way of performing direct numerical simulation of fluid-structure interaction at large Reynolds numbers. Adaptive second generation wavelet collocation tackles the problem of efficiently resolving a large Reynolds number flow in complicated geometries (where grid resolution should depend on both time and location), while Brinkman penalization efficiently implements moving solid boundaries of arbitrary complexity. Since the method is based on the primitive variables formulation of the Navier-Stokes equations, we need to solve a Poisson equation for the pressure at each time step. The wavelet basis provides a natural adaptive multilevel framework for a fast Poisson solver, and we have developed such a solver as part of this work.

Computation of the Probability Density Function and the Cumulative Distribution Function of the Generalized Gamma Variance Model

Xiaofang Ma
Department of Computer Science
University of Toronto

Numerical methods for computing the probability density function (pdf) (satisfying a relative accuracy requirement) and the cumulative distribution function (cdf) (satisfying an absolute accuracy requirement) of the generalized Gamma variance model are investigated.

A hybrid method is developed to calculate the pdf. This hybrid method chooses between several basic methods to evaluate the pdf depending on the value of the risk factor and the values of the shape parameters. Extensive numerical experiments are performed to verify the robustness of the proposed hybrid method. Comparison with some existing methods for special cases suggests that this hybrid method is accurate. To improve the performance of the hybrid method, a strategy suggested by Alex Levin is adopted in the present program.

A method for computing the cdf is also developed. Numerical comparisons for several special cases are carried out to verify the correctness and the accuracy of the proposed method.

Solving Diophantine Linear Equations and Rank-one Perturbed Systems by the ABS Methods

Nezam Mahdavi-Amiri
Sharif University of Technology, Tehran and
York University, Toronto

The class of ABS (Abaffy-Broyden-Spedicato) methods for solving systems of linear equations was introduced in 1984, and later it was extended to the scaled systems of equations. In 2001, we adapted these methods to solve Diophantine systems of linear equations. We show how the new methods are expanded to solve the scaled Diophantine systems. We also point out our recent result concerning an efficient computation of the solution for rank-one perturbed Diophantine systems by making use of the parameters computed through an application of the ABS method in solving the original system.

Spline Collocation on L- and T-shaped Regions

Kit-Sun Ng
Department of Computer Science
University of Toronto

Quadratic and Cubic Spline Collocation (QSC and CSC) methods of optimal orders of convergence have been developed for the solution of second-order Partial Differential Equations (PDEs) defined in a rectangular region. We extend the QSC and CSC methods to L-shaped and T-shaped regions. To do this, we need to properly define the QSC and CSC approximation spaces, and find appropriate collocation points so that the linear systems arising from QSC and CSC are solvable. We next develop optimal QSC and CSC methods for L- and T-shaped regions. The optimal methods are based on certain perturbations of the PDE operator, which involve the high order derivatives of the solution. We discuss how accurate approximations of the high order derivatives of the solution are computed. Our numerical results show that the global orders of convergence of the QSC and CSC approximations are three and four, respectively, while the QSC approximation is of fourth order locally on certain points.

The Complexity of Self-Regular Proximity Based Infeasible IPMs

Maziar Salahi, Tamás Terlaky, and Guoqing Zhang
Advanced Optimization Lab
Department of Computing and Software
McMaster University

Primal-Dual Interior-Point Methods (IPMs) have shown their power in solving large classes of optimization problems. In this paper a self-regular proximity based Infeasible Interior Point Method (IIPM) is proposed for linear optimization problems. First we mention some interesting properties of a specific self-regular proximity function, studied recently by Peng and Terláky, and use it to define infeasible neighborhoods. These simple but interesting properties of the proximity function indicate that, when the current iterate is in a large neighborhood of the central path, large-update IIPMs emerge as the only natural choice. Then, we apply these results to design a specific self-regularity based dynamic large-update IIPM in large neighborhood. The new dynamic IIPM always takes large-updates and does not utilize any inner iteration to get centered. An $O(n^2 \log \frac{n}{\epsilon})$ worst-case iteration bound of the algorithm is established. Finally, we report the main results of our computational experiments.

Poster Presentations

XLAB – An Interpreted Programming Language for Numerical Computing

Xiaorang Li
Department of Applied Mathematics
University of Western Ontario

XLAB (www.apmaths.uwo.ca/∼xli/xlab) is a high-level interpreted programming language for numerical matrix computing. It provides a convenient tool for performing matrix operations and solving numerical problems. The basic functionalities of Matlab have been implemented and several new features introduced. The main focus of this work is on improving the performance of program execution. The current version has been able to execute loops and recursive function calls considerably faster than other similar softwares. The ultimate goal is to realize a high-level and easy-to-use interpreted computing environment with the performance of compiled languages.

Implementing the New Self-Regular Proximity Based IPMs

Xiaohang Zhu, Jiming Peng, Tamás Terlaky, and Guoqing Zhang
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We present our experiences with an implementation of Self-Regular proximity based Interior Point Methods (SR-IPMs) for linear optimization. The implementation is based on a class of the new SR-search directions and the homogeneous self-dual model. To enhance the practical performance of the algorithm, we also employ the predictor-corrector strategy.

A software package McIPM is developed. It utilized optimization theory, interior point methods, numerical analysis, sparse matrix techniques, multi-thread programming, data synchronization, messages passing, and shared memory.

McIPM has been tested on the full NETLIB test suite and we present benchmarking computational results on this standard test set. Testing results are based on comparison of various SR-IPMs, e.g. different self-regular proximities, dynamic SR-IPMs, and normal equation approach vs. augmented system approach.

Extensive testing proves that the McIPM software package is competitive with state of the art software packages, such as LIPSOL, and self-regular proximity approach offers avenues for improvement when solving difficult problems.