Southern Ontario Numerical Analysis Day (SONAD) 2014  
Thursday May 15th  
Lecture Hall 001  
Accolade EAST (Building 92)  
York University

PROGRAM

9:00 – 9:30: Welcome, coffee and refreshments.


9:35 – 10:20: Prof. Ken Jackson (Toronto), “Computation of the loss distribution based on the structural model for credit portfolios”


10:40 – 11:00: Jonathan Calver (Toronto), “A 3-stage parameter estimation procedure for ODEs and DDEs”

11:00 – 11:15: Coffee

11:15 – 11:35: Dr. Alexander Chigodaev (York), “Implying longevity from annuity prices”


11:55 – 12:15: Dina Tsarapkina (Western), “Numerical pricing of spread options”


12:35 – 13:35: Lunch

13:35 – 14:20: A.J. Guillon (OpenCL Standards Committee), “Next generation numerical software with OpenCL”


14:40 – 15:00: Alena Antipova (Western), “Motion of colloidal discs and their pairs in a nematic liquid crystal”

15:00 – 15:20: Urmela Selventhiran (York), “Time-dependent calculation of tunneling ionization of the molecular hydrogen ion in a strong DC-field”
15:20 – 15:35 Coffee


16:15 – 16:35: **Ke Nian** (Waterloo), “Spectral ranking for anomaly detection”


---

**Prof. Ken Jackson, Computer Science Department, University of Toronto.**

**Computation of the loss distribution based on the structural model for credit portfolios** (9:35 – 10:20)

Credit risk analysis and management at the portfolio level is a challenging issue for financial institutions due to their portfolios' large size, heterogeneity and complex correlation structure. We have explored both asymptotic approximation methods and fast exact methods to compute the distribution of a loan portfolio's loss in the CreditMatrics framework.

In this talk, we focus on the fast exact methods, which improve the efficiency by exploiting the sparsity that often arises in the obligors' conditional losses. A sparse convolution method and a sparse FFT method are proposed, which enjoy significant speedups compared with the straightforward convolution method. We also construct truncated versions of the sparse convolution method and the sparse FFT method to further improve their efficiency. To balance the aliasing errors and roundoff errors incurred in the truncated sparse FFT method, an optimal exponential windowing approach is developed as well. With Meng Han and Alex Kreinin.

---

**Yousef Akhavan, Department of Mathematics and Statistics, York University.**

**High-order corrected explicit-implicit domain decomposition method for convection-dominated diffusion equations** (10:20 – 10:40)

High-order corrected explicit-implicit domain decomposition (HCEIDD) scheme is developed and analyzed for parallel approximation of the convection-diffusion equations with convection-dominated term and variable coefficients over multi-block sub-domains. The domain is divided into non-overlapping multi-block sub-domains. A high-order explicit scheme is first used to predict the interface values on the interface points of sub-domains.
A new high-order implicit modified upwind scheme is then proposed to compute the interior values in sub-domains. Finally, the interface values are corrected by an implicit scheme. The proposed scheme is of second-order accuracy in both time and space. Over arbitrary number of multi-block sub-domains, we analyze the stability and convergence and obtain the optimal error estimate of second-order accuracy in time and space. Numerical examples confirm the theoretical results.

Jonathan Calver, Computer Science Department, University of Toronto.

**A 3-stage parameter estimation procedure for ODEs and DDEs (10:40 – 11:00)**

We propose a 3-stage procedure for performing parameter estimation for ODE and DDE models. The first stage attempts to obtain improved initial guesses for a subset of the model parameters. The second stage uses a global optimizer to get us 'close' to the minimum value of our least squares objective function. The third stage uses a local optimizer to obtain the parameter estimates. We report the cost of performing the parameter estimation and show how each stage contributes to reducing the total cost.

Alexander Chigodaev, Department of Mathematics and Statistics, York University.

**Implying longevity from annuity prices (11:15 – 11:35)**

We use life annuity prices to extract information about human longevity by formulating a model that links the term structure of mortality and interest rates. We then invert the model and perform nonlinear least squares to obtain implied longevity forecasts. Methodologically, we assume a CIR model for the underlying yield curve and a cohort-varying Gompertz-Makeham (GM) law for mortality. Our main result is that over the last decade markets have been implying an improvement in longevity of an average of 6 weeks per year for males and 3 weeks for females. In the year 2004 market prices implied a 40.1% probability of survival to the age 90 for a 75-year old male (51.2% for a female) annuitant. By the year 2013 the implied survival probability had increased to 46.1% (and 53.1%). The corresponding implied life expectancy has increased (at the age of 75) from 13.09 years for males (15.08 years for females) to 14.28 years (and 15.61 years.)

Kai Ma, Cheriton School of Computer Science, University of Waterloo.

**An unconditionally monotone numerical scheme for the two factor uncertain volatility model (11:35 – 11:55)**

Under the assumption that two asset prices follow an uncertain volatility model, the maximal and minimal solution values of an option contract are given by a two dimensional Hamilton-Jacobi-Bellman (HJB) PDE. A fully implicit, unconditionally monotone finite difference numerical scheme is developed in
our work. Consequently, there are no time step restrictions due to stability considerations. The
discretized algebraic equations are solved using policy iteration. Our discretization method results in a
local objective function which is a discontinuous function of the control. Hence some care must be taken
when applying policy iteration. The main difficulty in designing a discretization scheme is development
of a monotonicity preserving approximation of the cross derivative term in the PDE. We will derive a
hybrid numerical scheme which combines use of a fixed stencil and a wide stencil based on a local
coordinate rotation. The algorithm uses the fixed stencil as much as possible to take advantage of its
accuracy and computational efficiency. The analysis shows that our numerical scheme is $l_{\infty}$
stable, consistent in the viscosity sense, and monotone. Thus, our numerical scheme guarantees
convergence to the viscosity solution.

Dina Tsarapkina, Department of Applied Mathematics, Western University.

**Numerical Pricing of Spread Options (11:55 – 12:15)**

This talk will focus on the applications of Monte Carlo methods to pricing financial spread options.
Spread options are very common in the commodity markets, where they can represent the spread
between the price of two different energies, or the same energy delivered at different locations or at
different times. As such, they satisfy partial differential equations with 2 'spatial' and one time variable.
They may be priced by determining the expected payoff, and the difficulty in pricing options arises from
the fact that an explicit expectation does not always exist. Using Monte Carlo methods allows us to price
options which do not have analytical solutions. The talk will focus on applications to spread options
which are abundant in the commodity market.

Zhe (Robert) Wang, Computer Science Department, University of Toronto.

**New approaches to importance sampling for portfolio credit risk valuation (12:15 – 12:35).**

The Gaussian Copula model, generally implemented through Monte Carlo simulation, is often used in
practice for Portfolio credit risk valuation. The commonly-used two-level structure, based on systemic
factors for the outer level and individual factors for the inner level, complicates the problem, making
traditional variance reduction techniques hard to apply. Glasserman et al. proposed a two-level
importance sampling approach based on exponential twisting.

Following the approach in Han's thesis, we use the Central Limit Theorem to approximate the
conditional losses for the inner level. Based on this approximation, we then propose two novel
approaches, motivated from research in machine learning, for importance sampling for the outer level.
Instead of finding the importance sampler through an optimization problem, our first approach
approximates the zero variance function by learning from the samples generated from Markov Chain
Monte Carlo. Our second approach treats the problem as a Bayesian inference problem and evaluates
the tail probability through Bayesian Monte Carlo. Numerical results show that these two new approaches are more efficient than the method of Glasserman et al. Moreover, our approach is more flexible. In particular, it can be generalized easily to multi-credit-state problems.

A.J. Guillon, OpenCL Consultant, OpenCL Standards Committee Member

**Next generation numerical software with OpenCL (13:35 – 14:20)**

OpenCL is a standard for heterogeneous computing that helps developers dispatch parallel computational functions to any processor. Developers can write a single application that can target any combination of CPUs, GPUs, or FPGAs within the system. This talk will motivate the need for heterogeneous computing, and contrast OpenCL numerical guarantees with IEEE-754. You will learn how the next generation of numerical software can leverage OpenCL for performance and portability.

Ikjyot Singh Kohli, Department of Physics and Astronomy, York University.

**Dynamical systems methods in early-universe cosmology (14:20 – 14:40)**

The dynamics of the large-scale structure of the universe is governed by the Einstein field equations of General Relativity. These equations, being 10 hyperbolic, nonlinear, coupled partial differential equations. Even with existing numerical techniques largely rooted in the Arnowitt-Deser-Misner (ADM) formalism, solving Einstein's equations numerically are still very difficult to do. I will discuss the method of orthonormal frames, in which the field equations reduce to a coupled system of nonlinear ordinary differential equations, that is, an autonomous dynamical system. Combining topological dynamical systems and numerical integration techniques, one obtains a very detailed description of the dynamics of the early universe. I will specifically describe the dynamics of a topologically closed universe in the presence of a viscous fluid, and show using the aforementioned techniques that the anisotropy grows chaotically as the model evolves toward the initial singularity, and dissipates as the model evolves towards the present epoch, representing a flat Friedmann-Lemaitre-Robertson-Walker universe.

Alena Antipova, Department of Applied Mathematics, Western University.

**Motion of colloidal discs and their pairs in a nematic liquid crystal (14:40 – 15:00)**

In the present work the motion of colloidal discs in a nematic liquid crystal was simulated using Lattice Boltzmann algorithm modified for the liquid crystals. Under the action of a rotating magnetic field the colloidal disc with perpendicular surface anchoring immersed in a nematic liquid crystal experiences a torque and continues turning following the field. However, when the disc reaches some critical position and the director field around it is highly distorted, the disc suddenly flips to minimize the free energy.
Analyzing this motion and, consequently, the behaviour of two discs under similar conditions placed close together, we examine the possible uses of this peculiar flip behaviour.

Urmela Selventhiran, Department of Physics and Astronomy, York University.

**Time-dependent calculation of tunneling ionization of the molecular hydrogen ion in a strong DC-field** (15:00 – 15:20)

The stationary Schrödinger equation for the hydrogen molecular ion, the simplest molecular system (H2+) is solved in prolate spheroidal coordinates. Eigenenergies for different internuclear distances were computed using a numerical method. The wave function is sampled on a finite grid of points in two dimensions. The stationary Hamiltonian as applied to the discretized wavefunction makes use of the Fourier transform for the computations of derivatives. The time-dependent Schrödinger equation is solved using an explicit – implicit method. To avoid flux reaching the grid boundaries a complex absorbing potential was added at distances far from the molecule. The wave packet properties were studied to isolate bound-state transitions from ionization. In this work the electric field is turned on over a short time, after which it is kept constant, before it is turned off in order to analyze the wave packet.

Vida Heidarpour, Computer Science Department, University of Toronto.

**A study of the alternating direction implicit and explicit methods for parabolic PDEs** (15:35 – 15:55)

We consider the numerical solution of parabolic partial differential equations (PDEs) by alternating direction explicit (ADE) and alternating direction implicit (ADI) methods. We first look at the not widely discussed ADE method. Our numerical experiments and truncation error analysis do not confirm the second order convergence claimed in previous studies. We then focus on investigating the effectiveness of different ADI methods, especially the modified Craig-Sneyd and Hundsdorfer-Verwer schemes, applied to two-dimensional convection-diffusion-reaction PDEs with mixed spatial derivative terms. Our experiments include the application of the ADI methods to the Black-Scholes PDE, for pricing European options on maximum or minimum of two assets. It is shown that the ADI schemes with proper choice of parameters perform very well in all situations, in terms of accuracy, convergence, and efficiency.

Luis A. Zarrabeitia, Computer Science, University of Ontario Institute of Technology

**Stereo tracking and motion estimation of blood droplets in flight** (15:55-16:15)

Multi-target tracking is a challenging problem, particularly when individual targets are indistinguishable from each other and the background. We present a method for reconstructing three-dimensional (3D) trajectories of targets in flight captured using multiple cameras. We employ a track-before-detect
strategy; that is, predictions based on established motion patterns learned from active tracks are used
to filter incoming measurements and to extract 2D trajectories from recordings from each camera.
Common prediction strategies---e.g., position-velocity Kalman Filters---rely on physically meaningful but
simplified motion models. Such techniques are generically unable to compensate for distortions
introduced by aerodynamic drag forces or perspective projections. Instead, we use a tuned polynomial
least-squares approximation to the local motion of the targets in the image plane.

We avoid the assumption of simultaneity that underpins traditional triangulation techniques for 3D
reconstruction using a global motion model that accurately describes the droplet motion in space. In our
approach, we solve the 3D reconstruction and parameter estimation problems jointly, allowing us to
process real-world experiments with misdetection ratios as high as 50%. Using synthetic experiments
with simulated noise and misdetection ratios ranging from 10% to 100%, we demonstrate the efficacy of
our joint reconstruction-estimation technique in comparison to approaches that solve both problems
independently.

---

Ke Nian, Cheriton School of Computer Science, University of Waterloo.

**Spectral ranking for anomaly detection** (16:15 – 16:35)

Anomaly detection is the problem of finding deviations from expected normal patterns. Its many
applications include fraud detections, medical image monitoring, network intrusion detections, and
military surveillance. Obtaining accurate labels for fraud detection, especially labels for anomalous
cases, is costly and time consuming, if not practically infeasible. This makes supervised anomaly
detection less desirable. We propose a novel unsupervised spectral ranking method for anomaly (SRA)
detection. Based on the 1st non-principal eigenvector of the Laplacian matrix, the proposed SRA can
generate anomaly ranking with respect to either a single majority class or multiple majority class. Using
both synthetic and real data sets, we show that our proposed SRA is an effective alternative to the state-
of-art unsupervised anomaly ranking methods. In addition, we show that, for an automobile insurance
fraud detection problem, unsupervised SRA method surpasses most of the state-of-art unsupervised
anomaly ranking methods in terms of performance and robustness to parameter tuning.

---

Varvara Nika, Department of Mathematics and Statistics, York University.

**EigenBlockCD-2: A change detection algorithm of medical images using dictionary learning techniques
and PCA** (16:35 – 16:55)

Existing change detection methods in medical imaging include many preprocessing steps and rely mostly
on statistical analysis tool. We present and improved version of Eigen-Block Change Detection algorithm
(EigenBlockCD), which identifies the clinical changes between two consecutive MR images by performing
global initial registration followed by local registration and detection of significant and relevant changes
based on dictionary learning techniques. We use PCA to reduce the dimensionality of the local
dictionaries and the redundancy of data. We examine the differences between L1 and L2 norms and
demonstrate the advantages of L2 norm as a better similarity measure. Experimental results and
performance analysis show that EigenBlockCD works better than previous methods.