Southern Ontario Numerical Analysis Day 2008
Program

9:45am - 10:30am: Dr. Christina C. Christara (Toronto)

Title: Computational PDEs: accuracy, efficiency, adaptivity and parallelism

Abstract: Partial Differential Equations (PDEs) are an indispensable tool in solving many scientific and engineering problems, therefore, many researchers have developed methods for the solution of PDEs. However, since by definition PDEs suffer from the curse of dimensionality, numerical methods for PDEs are greedy for computational resources. This fact and the increasing demand from scientists and engineers to solve larger and larger models make the study of high-performance methods for the solution of PDEs an active area of research. Performance depends, among other, on accuracy and efficiency. Important factors that play a role in the accuracy and efficiency of a numerical method for PDEs are the discretization method for the PDE, the mesh which the method is applied to, and the solution technique for the resulting set of algebraic equations.

In this talk, we review certain numerical methods for PDEs. Emphasis is given on spline collocation, a high accuracy discretization method, on adaptive techniques that optimize the location of discretization points, and on Fast Fourier Transform (FFT) solvers and preconditioners, which have almost optimal complexity for the solution of the resulting linear system. The parallel computation of some methods and their communication requirements on distributed memory architectures are discussed.

10:30am - 10:55am: Dr. Silvana Ilie (Toronto)

Title: Adaptivity and Computational Complexity of Numerical Solutions of ODE

Abstract: In this talk, I describe a new computational cost model for numerically solving ordinary differential equations (ODE), both initial value problems and boundary value problems, with a view to generating optimal grids for local error control. For grid generation, we introduce an auxiliary independent variable and find a grid deformation map which transforms the equidistant grid into a non-equidistant computational grid in the original independent variable. An optimal deformation grid is obtained by a variational approach.

We investigate the cost of the method and compare it to the cost of using equidistant grids. The well-known and debated result of the standard theory of information–based computational complexity (Werschulz, 1991) states that " Adaptivity is no better than non-adaptivity". However, we find that, if the principal error function is non-constant, adaptive methods are always better than non-adaptive methods. (With Gustaf Söderlind and Rob Corless)

10:55am - 11:15am: Jian Wang (Waterloo)

Title: Maximal Use of Central Differencing for Hamilton-Jacobi-Bellman PDEs in Finance

Abstract: In order to ensure convergence to the viscosity solution, the standard method for discretizing HJB PDEs uses forward/backward differencing for the drift term. In this paper, we devise a monotone method which uses central weighting as much as possible. In order to solve the discretized algebraic equations, we have to maximize a possibly discontinuous objective function at each node. Nevertheless, convergence of the overall iteration can be guaranteed. Numerical experiments on two examples from the finance literature show higher rates of convergence for this approach compared to the use of forward/backward differencing only. (With Peter Forsyth)

11:30am - 11:50am: Hossein Zivari Piran (Toronto)

Title: The Sensitivity Analysis and Parameter Estimation of Mathematical Models Described by Differential Equations

Abstract: Differential equations are one of the most frequently used tools for mathematical modeling in engineering and life sciences. Usually a mathematical model used for the simulation of a real phenomenon contains some parameters. These parameters are used to make the model applicable in similar situations and also to analyze the effect of uncertainties. An essential part of the process of constructing a mathematical model is the analysis of the effect of small changes in model parameters on the state variables (sensitivity analysis). Furthermore, for the simulation of the model in a special practical case the value of the parameters should be known to the simulator. In most cases a direct measurement is not possible and an indirect method is used based on some observations from the phenomenon. In this talk, first we review the existing techniques for the numerical computation of sensitivities and parameter estimation of ordinary differential equations and then we introduce the adapted techniques for delay differential equations.

11:50am - 12:10pm: Roman Naryshkin (UWO)

Title: Portfolio Optimization under Habit Formation

Abstract: The standard portfolio optimization problem for both discrete and continuous time cases will be considered. In the standard formulation the utility of consumption at any given time depends only on the amount consumed at that time. However, it is both theoretically and empirically reasonable that a persons utility of consumption would depend on past consumption history. Economists term this 'habit formation'. It will be shown how one can generalize the standard utility function to account for the habit formation. Analytical and numerical methods including dynamic programming in discrete time and the Hamilton-Jacobi-Bellman equation in continuous time for finding the optimal solution will be presented. The results for the habit formation case will be compared with the ones for the standard case. (With Matt Davison)

12:10pm - 12:30pm: Qiang Guo (York)

Title: A Splitting Wavelet Method for Solving Aerosol PDEs in Atmospheric Environment

Abstract: The significance of aerosol particles in the atmosphere has been recognized for many years due to their effects on climate change and human health. The mathematical models are the nonlinear integro-partial differential equations on time, size and space, which describe different processes of atmospheric aerosols including condensation, nucleation, coagulation, deposition, sources as well as turbulent mixing. In this study, a new splitting wavelet method is developed to solve the general aerosol equations. The proposed method reduces the complex aerosol dynamic equations to one dimensional directional splitting equations in each time interval. The wavelet method and the upstream finite difference method are alternately used to solve the size directional and spatial directional splitting equations in each time interval. Numerical experiments are given to show the efficiency of the method. Meanwhile, we will address some adaptive numerical issues for the aerosol dynamic problems. (With D. Liang and S. Gong)

13:30pm - 14:10pm: Dr. Hugh Couchman (SHARCNET)

Title: The SHARCNET Computational Environment

Abstract: SHARCNET is a collaboration of 17 universities, colleges and institutes in Ontario providing a range of high-performance computing and related services to researchers at its member institutions. The range of services is structured to cater to both new users who are eager to take advantage of large-scale computation as well as to experts who are already undertaking forefront computations. The talk will discuss the services and tools that SHARCNET provides, including our systems, software, training, user support, hosting, collaboration environments, and the fellowships, chairs and programming competitions.

14:10pm - 14:35pm: Dr. Ranga Sudarsan (Guelph)

Title: Bee Cool : Ventilation in an Industrial Beehive during summer

Abstract: Abstract: Honeybees work hard to maintain temperature and humidity levels inside their beehive within narrow limits to ensure optimal growth conditions for their brood as well as to optimize their finite energy resources. The temperature inside the beehive is determined by a complex set of interacting non-linear energy transfer processes namely metabolic heat generation by active and passive honeybee's, movement of bee's inside as well from outside of hive, forced convection created by fanning bees, evaporative cooling resulting from loss of moisture from nectar etc. In addition to its role in temperature control, movement of air inside the beehive also enables the exchange of gases (oxygen and carbon-dioxide) between the bee's inside the hive and the ambient air.

Despite its extensive use in honey bee farming practice, little qualitative and quantitative information is available about the features of the flow inside an industrial honey beehive. In this study, we construct a model approximating the thermal conditions inside an industrial beehive and simulate the 3-D flow driven by these conditions. For the fluid flow simulation we use Fluent, a commercial state of the art fluid mechanics simulator and embed our bee-model using the user-defined programming features present in Fluent. Visualization of the model results reveal interesting features of the flow. A thorough parametric investigation has helped us identify how the different model parameters control the flow circulation.Using our model, we try to evolve a design philosophy and develop quantitative measures that can be used to evaluate different beehive design modifications. In general, the ability to control flow circulation by minor changes in beehive design has the potential for providing ideal conditions for the bee's to improve worker efficiency, brood rearing, honey production, and general colony health. (With C. Thompson and H. Eberl)

14:35pm - 14:55pm: Guoyu Wang (Toronto)

Title: Multigrid and Spline Collocation Methods on Non-Uniform and Adaptive Grids

Abstract: Numerical methods for the solution of one-dimensional second-order differential equations on non-uniform grids are presented. The methods are based on combining the multigrid and spline collocation methodologies. Appropriate restriction and extension operators for multigrid methods are developed for quadratic and cubic splines that satisfy various boundary conditions (BCs) on non-uniform grids. The multigrid methods are applied to quadratic spline collocation (QSC) and cubic spline collocation (CSC) equations arising from the discretization of one-dimensional second-order differential equations. The convergence analysis of a two-grid method integrated with a damped Richardson relaxation scheme as smoother shows the rate of convergence is faster than 1/2 for a model second order equation with homogeneous Dirichlet BCs. The numerical experiments of full multigrid methods are performed on various one-dimensional second-order differential equations discretized on non-uniform grids, which are either prescribed or adaptively generated. The multigrid methods are applied to problems with high variations, such as boundary or interior layers, and the conditions under which they are convergent and efficient are studied. The numerical results confirm our analysis.

14:55pm - 15:15pm: Amber Holdsworth (McMaster)

Title: Making Waves in Epidemiology: Analysis of Time Series using Wavelet based Techniques

Abstract: Wavelets offer unique tools for data analysis. We begin with a brief introduction to wavelet analysis with a focus on applications. Then, we apply these techniques to epidemiological time series. Two types of models are encountered in epidemiology: mechanistic and statistic models. Our goals are to improve mechanistic modeling and to obtain new, or improved descriptions of the data. Mechanistic models are generated deterministically and stochastized to simulate observed data. The stochastized models exhibit fluctuations that could be indicative of the presence of noise, or an inherent fractal structure in the data. Using wavelet denoising we make comparisons between the numerical models and the observed data. We hope this will reveal the true nature of the data; is the noise Gaussian, or are these fluctuations a true feature of the dynamics? If noise is present in the numerical model, denoising should improve the model overall. To test this we compute the wavelet power spectrum of the denoised data for comparison. Next, we apply a wavelet based multifractal formalism to the deterministic and stochastic models. If stochastizing the model introduces a fractal structure to the data, the singularity spectrum will change. The results of our study will help to characterize the fine scale structure of real, and numerically generated data. Our hope is that this will improve mechanistic modeling in epidemiology and possibly offer a new perspective on data analysis in this important field.

15:30pm - 15:50pm: Lin Xu (Waterloo)

Title: Real-time Rigid Medical Image Registration

Abstract: Physicians often need to do image registration, i.e. aligning two images from different sources, for more effective surgical operations. In the registration process, besides accuracy, efficiency is also an important issue in practice. In this talk, I will first give an overview of medical image registration. After that, I will talk about using the cutting-edge GPU technology to improve the efficiency of registration process. I will also discuss the issues of multi-modality registration. Numerical results will be presented to illustrate the effectiveness of our model.

15:50pm - 16:10pm: Don Morgan (McMaster)

Title: Accuracy and Stability in Mass-Spring Systems for Sound Synthesis

Abstract: This presentation examines the stability and accuracy of mass-spring systems used in sound synthesis. We show that the standard method used in mass-spring systems, when used on undamped systems, has no numerical damping, but does have frequency warping and is unstable at frequencies above $1/\pi$ times the sampling rate. As well, we find that for lightly damped systems, the damping is accurate, but large damping can cause instability even at low frequencies. We compare the standard method with two higher order numerical methods: the fourth order Runge-Kutta, and the VEFRL algorithm, a fourth order symplectic algorithm. We find that the VEFRL algorithm is much more accurate than the standard method, but that this increase in accuracy does not noticeably affect the quality of the sound produced by the mass-spring system when used to simulate a vibrating string. The increased accuracy of the VEFRL method may, however, be useful for mass-spring spring systems used in physics or engineering requiring high accuracy.

16:10pm - 16:30pm: Cheng Liu (York)

Title: Reassignment of the Stockwell Spectrogram

Abstract: Time-frequency representations are widely used to reveal the frequency-varying and multi-component characteristics of non-stationary signals. Due to the Heisenberg's inequality, however, most time-frequency representations suffer from the tradeoff between the time and frequency resolutions. To overcome such limitations, the reassignment method was proposed with the short-time Fourier transform in literature. By re-locating the signal energy to their instantaneous frequency positions in the time-frequency plane, the reassigned short-time Fourier transform provides a better description of the non-stationary feature of signals. Here, we apply this reassignment method to the recently developed Stockwell transform. Such extension is plausible in terms of the multi-scale characteristic of the Stockwell transform. Numerical simulations will be presented to show the improvement. (With Hongmei Zhu)

16:30pm - 17:15pm: Dr. Brian Wetton (UBC)

Title: Asymptotic Error Analysis of Finite Difference Methods

Abstract: When computing approximations to Differential Equation problems with smooth solutions using regular grids, the error has additional structure. For second order methods applied to elliptic or parabolic problems, an expansion for the error can be constructed that is regular in the grid spacing. This expansion can be used to justify convergence for nonlinear problems, and is an easy way to see why convergence with higher regularity is observed (a phenomena sometimes called superconvergence in the Finite Element community). When artificial boundary conditions are introduced for higher order finite difference methods, numerical boundary layers result. Identi-

fying the types of errors that are generated by a given scheme and the order at which they occur can be called Asymptotic Error Analysis. Several examples of the technique and its uses will be given. This will be an overview talk also with some material useful to anyone trying to implement ”unusual” boundary conditions.