Contributed Papers
Communications libres
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VAHID H. ANVARI, University of Saskatchewan, 106 Wiggins Road, Saskatoon, SK, Canada S7N 5E6
The Fuzzy Modeling Approach for Qualitative Description of Biological Systems

It is believed that most of biological procedures cannot be fully described by quantitative dynamical models, since biological systems are hierarchical and highly interconnected and the size of a quantitative model grows with the complexity of the system. On the other hand, restricting the model to a small set of variables inevitably leads to an often unacceptable level of uncertainty in the inference. Modeling of complex systems involves two kinds of uncertainty, one type is randomness which models stochastic variability; the other is fuzziness which models measurement imprecision due to incomplete information or linguistic structure. Numerous biological phenomena is described and explained linguistically by human observers. The derivation of suitable mathematical models is a necessary step in order to study these phenomena in a systematic manner. Fuzzy modeling is the most effective approach for transforming linguistic data into mathematical formulas and vice versa. This talk demonstrates the advantages of using fuzzy modeling to analyze, simulate, test the influence of parameters, and predict the behavior of the system.

MAHSHID ATAPOUR, University of Saskatchewan, 106 Wiggins Road, Saskatoon, SK S7N 5E6
Asymptotic Behavior of the Linking Probability of 2-Component Links in a Lattice Tube

In this talk we will explore the homological linking probability of ring polymers confined to a tube. We model a pair of polymers by two self-avoiding polygons (2SAP) which span a tubular sublattice of $\mathbb{Z}^3$. Then we use the linking number of the 2SAP to determine whether the two polygons are linked. We prove a pattern theorem for 2SAPs and establish a lower bound (with probability one) on the rate of increase of their linking number. As a result, we show that the linking probability of 2SAPs approaches one as the size of the 2SAP goes to infinity. We also show that the linking number of an n-step 2SAP is at most linear in n.

MHENNI BENGHORBAL, Concordia University, Montreal, QC, Canada
Unified Formulas for Integer and Fractional Order Symbolic Derivatives and Anti-Derivatives of the Power-Inverse Trigonometric Class

This is a contination of a series of papers introduces a complete solution to the problem of symbolic differentiation and integration of any order (integer, fractional, real, or symbolic) for most of elementary and special functions by introducing unified formulas in terms of the Fox H-function which can be simplified in many cases to less general functions such as the Meijer G-function and the Hypergeometric function. In this talk, we illustrate the idea on the *power-inverse trigonometric class*. In particular, the *power-inverse sine class*

$$\Big\{f(x) : f(x) = \sum_{j=0}^{\ell} p_j(x^{\alpha_j}) \arcsin(\beta_j x^{\gamma_j}), \alpha_i \in \mathbb{C}, \beta_i \in \mathbb{C}\backslash\{0\}, \gamma_i \in \mathbb{R}\backslash\{0\}\Big\}, \tag{1}$$

the *power-inverse cos class*

$$\Big\{f(x) : f(x) = \sum_{j=0}^{\ell} p_j(x^{\alpha_j}) \arccos(\beta_j x^{\gamma_j}), \alpha_i \in \mathbb{C}, \beta_i \in \mathbb{C}\backslash\{0\}, \gamma_i \in \mathbb{R}\backslash\{0\}\Big\}, \tag{2}$$

and the *power-inverse tangengial class*

$$\Big\{f(x) : f(x) = \sum_{j=0}^{\ell} p_j(x^{\alpha_j}) \arctan(\beta_j x^{\gamma_j}), \alpha_i \in \mathbb{C}, \beta_i \in \mathbb{C}\backslash\{0\}, \gamma_i \in \mathbb{R}\backslash\{0\}\Big\}, \tag{3}$$

The approach does not depend on the integration techniques. Arbitrary order of differentiation is found according to the Riemann–Liouville definition, whereas we adopt the generalized Cauchy n-fold integral definition for arbitrary order of integration. Many examples will be given using a Maple code developed by the author.

LUKE BORNN, University of British Columbia
Residual-based approaches for structural health monitoring

The use of statistical methods for anomaly detection has become of interest to researchers in many subject areas. Structural health monitoring in particular has benefited from the versatility of statistical damage-detection techniques. I will present residual-based approaches for damage-detection, in particular some novel methods relying on non-linear autoregressive ideas to improve model fit and detection rate. I will also discuss ideas for combining sensory output to increase detection power.

CLAUDIA DANIELA CALIN, University of Alberta, Department of Mathematical and Statistical Sciences, 632 CAB, Edmonton, Alberta, T6G 2G1
Similarity Solutions for Coagulation Equations

Similarity or group invariant solutions play a distinguished role in the analysis of qualitative properties of solutions of several nonlinear problems. In this talk I will present two generalized methods that determine similarity solutions for the coagulation equations that describe the evolution of the size distribution function of a system of particles. Analytical solutions to the coagulation equations and explicit formulas for the moments of solutions are only known for a restricted class of coagulation rates (coefficients). Similarity solutions are interesting particular solutions that describe the behavior of the general solutions of the coagulation equations. The first is an indirect method applied to a partial differential equation associated with a new modified form of the coagulation equation. This method determines a local Lie group of point transformations that leaves the PDE invariant. The second method is a new generalized version of the direct methods that determine the symmetry group of the point transformations to integro-differential equations. We apply this second method to the coagulation equation directly. These methods provide us with a new family of exact and asymptotic solutions to the coagulation equations which can be further used for numerical studies. The advantage of these methods over previous methods is that in some special cases the expression of the total mass of particles does not need to be known in advance.

CHRISTINA CHRISTARA, University of Toronto, Dept. Comp. Sci., 10 King's College Road, Toronto, Ontario, Canada
Quartic spline collocation for fourth-order boundary value problems on rectangles with an application to the biharmonic Dirichlet problem

Bi-quartic spline collocation methods for the numerical solution of fourth-order boundary value problems on rectangular domains are presented. A particular instance of these methods is applied to the biharmonic Dirichlet problem.

The bi-quartic spline collocation methods use the midpoints of a uniform partition, the boundary midpoints and the corners as collocation points. While the standard bi-quartic spline method provides second-order approximations, two bi-quartic spline collocation methods, the one-step (extrapolated) and the three-step (deferred-correction) methods, produce approximations which are sixth order at gridpoints and midpoints, and fifth order at other points. Both are based on high order perturbations of the differential and boundary conditions operators.

The properties of the three-step method matrices arising from a restricted class of problems are studied. Analytic formulae for the eigenvalues and eigenvectors are developed, and related to those arising from quadratic-spline collocation matrices. These properties lead to a fast solver for the biharmonic Dirichlet problem on rectangles. The fast solver is based on Fast

Fourier Transforms applied to an auxiliary biharmonic problem with Dirichlet and second derivative boundary conditions along the two opposite boundaries, and on preconditioned GMRES applied to a problem related to the two opposite boundaries. By analyzing the eigenvalues of the preconditioned matrix, the solver is shown to have complexity $O(N^2 \log N)$ on a $N \times N$ partition. Numerical experiments from a variety of problems, including practical applications and problems more general than the analysis assumes, verify the accuracy of the discretization scheme and the effectiveness of the fast solver.

Joint work with Jingrui Zhang.

FRANÇOIS GILBERT, Université de Montréal, 2920 Chemin de la Tour, Montréal, QC H3T 1J4
Network design under a discrete choice: a bilevel programming approach

Network design problems fit the Stackelberg game framework. Two types of players are involved: leader and follower. A single leader plays first and has perfect knowledge of the followers' strategy, while the followers only responds to whatever action the leader has taken. In our case the leader's goal is to maximize his revenue by setting tolls and capacities on some of the network links. This forms the basis of the generic revenue management problem. The followers' response will be described by an entropy minimization based discrete choice model parametrise by the leader's policy. This setup is most naturally formulated as a bilevel mathematical program. The resulting revenue maximization problem is differentiable but non-concave and does not directly lend itself to global resolution tools such as the combinatorial techniques often used for network design problem.

We first consider the pricing problem, where capacities are fixed. In order to find good toll policies we formulate and solve to optimality several mixed integer approximate formulations. Approximation schemes involve piecewise linear, or quadratic, approximations of the nonlinear terms involved in the followers' flow distribution. These approaches are combined with local methods taking further advantage of the problem differentiability. Getting optimality certificates on the original problem is in general out of the question. Yet an upper bound is obtained which does give some guaranty of global optimality. The case where tolls and capacities are both decision variables is the focus of the last section of the talk and involves solving a restriction of the problem to a discrete set of candidate capacities.

QIANG GUO, York University
Adaptive splitting wavelet method for atmospheric problems

Aerosol particles in the atmosphere have big significance due to their effects on climate change and human health. A new and robust wavelet-based splitting method has been developed to solve the general aerosol equations. The considered 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.

Wavelet technique has been a great tool for adaptivity and multi-resolution schemes to obtain solutions of systems which vary dynamically both in space.

The proposed method reduces the complex general aerosol dynamic equation to two directional splitting equations. Because there are steeply varying number densities across a size range, we develop the adaptive technique in which the solution is represented and computed in a dynamically evolved adaptive grid. Numerical experiments are given to show the effective performance of the method.

SABER HAMIMID, UMBB, avenue de l'Indépendance, 35000 Boumerdes, Algérie
Numerical simulation of electrically conducting liquid flows in an external magnetic field

The present study is devoted to the problem of onset of oscillatory instability in convective flow of an electrically conducting fluid under an externally imposed time-independent uniform magnetic field. Convection of a low-Prandtl-number fluid in a laterally heated two-dimensional horizontal cavity is considered. Fixed values of the aspect ratio (height/width$= 1$) and Prandtl number ($\mathrm{Pr} = 0.015$), which are associated with the horizontal Bridgman crystal growth process and are commonly used for benchmarking purposes, are considered. The effect of a uniform magnetic field with different magnitudes and orientations on the stability of the two distinct branches (with a single-cell or a two-cell pattern) of the steady state flows is investigated. The

combined effects of the magnetic field and the surface tension are presented graphically in terms of isotherm and streamline plots. The effects of varying the physical parameters on the rate of heat transfer from the heated surface of the enclosure are also depicted.

LARBI HAMMADI, 1 Laboratoire de rhéologie, transport et traitement des fluides complexes et Laboratoire de matière et système complexes (MSC), Paris 7 France

Effet de traitement thermique sur le comportement physico-chimique et rhétorique des boues activées de station d'épuration

Le traitement des eaux, qu'il s'agisse de production d'eau potable où d'épuration d'eau usée d'origine urbaine ou industrielle, conduit toujours à la formation de boues que l'on sépare et de l'eau traitée. Ces boues se présentent à la sortie de la station d'épuration comme un liquide à forte teneur en eau. La teneur élevée en substance polluantes interdit le plus souvent leur rejet dans le milieu naturel sans précaution. Pour évaluer l'aptitude de ces boues au traitement, déterminer quels traitements leur faire subir, estimer les risques de pollution et enfin connaître leurs possibilités de réutilisation (agricole, énergétique ou autre). Dans ce cadre que étant défini l'objet de cette étude. L'étude consiste à étudier l'effet de traitement thermique sur le comportement physico-chimique et rhétorique des boues activées de station d'épuration. Le traitement thermique des boues activées montre que l'augmentation de la température provoque une augmentation du pH et une diminution de la demande chimique en oxygène (DCO), et du rapport entre matières volatiles en suspension et matière en suspension (MVS/MES). Concert l'aspect rhéologies pour les boues étudiées, le seuil de contraint diminue avec l'augmentation de la température dans le même temps la viscosité apparent des boues diminue suivant une loi de puissance avec l'augmentation de la température.

JIALIN LI, University of Manitoba, Department of Electrical and Computer Engineering

Liquid Level Measurement Using Guided Wave Radar Approach

In many industrial processes, measuring and monitoring liquid level in tanks definitely ranks high in importance above many other parameters measured in the seal environment. Over time, mechanical level detection devices have given way to newer technologies, with accurate readings, wide rang of detection capability, and wide variations in operating temperature and pressure and low dielectric constants. With many of these features, microwave-based technology now has become firmly established and improved mainly consisting in the development of the excitation and data acquisition electronics. Guided Wave Radar (GWR) is one of the applications using microwave radar technology detecting liquid level changes. The basis for GWR is TDR (Time Domain Reflectometry). In this application, TDR technology achieves its non-mechanical level detection by measuring the flight time of a single sharp waveform. When the pulse of radar energy reaches the liquid level where a change in impedance occurs, part of the signal is reflected back to the transmitter. At the data acquisition stage, sampling electronics employs ETS (Equivalent Time Sampling), obtain repetitive signals data and measure the duration between transmitter and reflected signal. In the meantime, system must be sensitive to small level changes (less than 5mm).

The project involves designing a prototype level sensor including the excitation and data acquisition electronics to meet specifications and requirements aforementioned. Some basic mathematical analysis of the behavior of electrical transmission lines (GWR) is discussed. The distance versus resolution relationship is developed, as well as the verification in simulation models. The excitation circuit is designed and also simulated using SPICE software together with some measurement results presented to show the resolution and accuracy.

JESSICA McDONALD, University of Waterloo

Achieving maximum chromatic index in multigraphs

The chromatic index of a multigraph M, denoted by $\chi'(M)$, is the minimum number of colours needed to colour the edges of M such that such that adjacent edges receive different colours. Shannon (1949), Vizing (1964) and Goldberg (1984) have all established well-known upper bounds for the chromatic index of M. In this talk we ask: when is $\chi'(M)$ maximum? That is, when does $\chi'(M)$ achieve a particular upper bound?

Our main result in this talk is to characterize those multigraphs which achieve Goldberg's upper bound, generalizing a 1968 result of Vizing which characterizes those multigraphs which achieve Shannon's upper bound. There is no known characterization for

those multigraphs which achieve Vizing's upper bound, however we will discuss some partial results towards this, and address the issue of the complexity of this problem.

ABAS SABOUNI, University of Manitoba
Hybrid optimization method for microwave breast cancer detection

Breast cancer has long been one of the most common forms of cancer in women. One of the challenges facing the medical community is the early detection and treatment of breast cancer. Microwave-based imaging techniques offer a number of benefits, including improved contrast of malignant lesions and safety. Microwave imaging is the process by which radiofrequency electromagnetic waves are used to generate an image of the body to enable physicians to diagnose disease. In an effort to improve this imaging strategy, a variety of mathematical method has been developed in the literatures. Recently, the microwave tomography method has been developed by solving Maxwell's partial differential equations with Finite-Difference Time-Domain (FDTD) as well as solving nonlinear reconstruction problem using iterative algorithms.

In this talk, we consider an accurate numerical model for breast phantom derived from Magnetic Resonance Imaging (MRI) data that incorporates water content and frequency dependency of dielectric properties for breast tissues. The microwave tomography method based on FDTD and hybrid Genetic Algorithm (GA) was applied to phantoms derived from this data in order to locate, characterize, monitor, and treat the breast cancer.

With contributions from Mr. Ali Ashtari, Prof. Sima Noghanian and Prof. Stephen Pistorius (all from University of Manitoba).

SEYED JAFAR SADJADI, Iran University of Science and Technology
A new mathematical modeling and a genetic algorithm search for milk run problem

The idea of milk run has been used in the context of logistic and supply chain problems in order to manage the transportation of materials. In this paper, we propose a new milk run method, as a mixed integer approach, to manage supply chain problems. Since the resulted problem formulation is NP-hard we use some meta-heuristic and compare the results with the optimal solutions of the proposed milk run method. The mathematical modeling of this paper is purposely customized for a special case of an auto industry. We implement the mathematical formulation and the meta-heuristic using some actual data and compare the results with the current strategy. The preliminary results indicate that the proposed method could provide a practical tool to significantly reduce the cost of logistic.

SEYED JAFAR SADJADI, Islamic Azad University, Science and Research Branch
A Robust Optimization Model for Resource Allocation Problem with Different Time Cycles

In many resource allocation problems, we are faced with the environments that change continuously. The existing uncertainties may cause some changes on the return values of the investment alternatives during the planning horizon which could lead us to have even infeasible solutions. In this talk we consider a new robust resource allocation problem. The proposed method of this talk consider an investment strategy where different investment alternatives may return in various time cycles and resources can be allocated only at the beginning of each period. We develop a mathematical formulation for the problem of robust resource allocation. The implementation of the proposed method is discussed through a numerical example.

SAMIRA SADAT SAJADI, Iran University of Science and Technology, Narmak, Tehran, Iran
A statistical model to estimate information technology spending

In this talk we present a statistical model to estimate demand for Information Technology. The statistical function is based on Engle model where demand is a model of home non-food expenditure as well as the size of the family. We use an Ordinary Least Square (OLS) method for our estimation and validate the model using actual information of a Middle East region country. The method is also validated using different statistical tests.

DMITRY TRUKHACHEV, University of Alberta, 2nd floor ECERF, Edmonton, AB, Canada T6G 2V4
Generalized Modulation

Classic modulation in communication theory is based on representation of an information-bearing signal as a linear combination of orthonormal basis waveforms. At the receiver the signal is usually passed through a bank of filters matched to the orthogonal basis waveforms and simple post processing acquires the transmitted information. In reality, however, specifically in modern communication systems, the transmitted signal is rather viewed as a combination of correlated waveforms. For example in Multiple Input Multiple Output systems the base waveforms can de-orthogonalise during the transmission and in random Code Division Multiple Access they are chosen randomly and independently. Therefore, fundamental understanding of general modulation and demodulation process constitutes an important problem in modern digital communications.

We consider signals represented as a linear combination of random waveforms with bounded average cross-correlation. The signals are transmitted over additive white Gaussian noise channel. It is well known that signal reception with optimum maximum-likelihood decoders quickly becomes impractical due to complexity constraints. On the other hand, linear signal separation via, for example, minimum mean-square error (MMSE) filtering provides close to optimal performance only for small information loads. We propose a modulation format introducing redundancy and interleaving to the data at the transmitter so that at the receiver the information can be recovered using an iterative distributed message-passing detection algorithm designed to solve inference problems on graphical models. We prove that the capacity of the channel can be approached to within less than 1 bit per dimension as the number of base signal waveforms becomes large.

HENRY VAN ROESSEL, University of Alberta, Edmonton
Some Exact Solutions to the Coagulation Equation with Product Kernel

An important phenomenon in a wide variety of processes in physics, chemistry, biology, medicine and engineering is the coalescence or aggregation of small clusters of particles into larger ones. Examples include, but are not limited to, polymerization processes in polymer science, coagulation processes in aerosol and colloidal physics, planet and galaxy formation.

Coagulation processes are governed by integro-differential equations known as coagulation equations. The nature of the solution of these coagulation equations will depend on the form of the coagulation kernel that appears in the equation. One interesting feature of these equations is that, depending on the coagulation kernel used, mass need not be conserved. The phenomenon whereby conservation of mass breaks down in finite time is known as "gelation" and is physically interpreted as being caused by the appearance of an infinite "gel" or "superparticle".

For certain forms of the coagulation kernel exact solutions to the coagulation equation can be found.

RALF WITTENBERG, Simon Fraser University, Burnaby, BC
Rigorous Bounds on Rayleigh–Bénard Convection with Conductive Plates

Considerable experimental and theoretical effort has been devoted to obtaining the asymptotic scaling of the enhanced bulk heat transport in turbulent Rayleigh–Bénard convection, measured by the Nusselt number, in terms of the temperature drop across the fluid, given by the Rayleigh number; however, the usual assumption of fixed temperature across the fluid is mathematically and experimentally inadequate.

We formulate a variational bounding principle to obtain rigorous theoretical estimates for the Nusselt number as a function of the Rayleigh number in finite Prandtl number turbulent convection. We are able to treat a full range of thermal boundary conditions between the fixed temperature and fixed flux extremes in a uniform formulation, and show that the usual fixed temperature assumption is a singular limit of the full problem. We also obtain analytical bounds in the physically realistic case of a fluid bounded by conductive plates, and discuss some generalizations.