AN13 and CT13 Abstracts

2013 SIAM ANNUAL MEETING

July 8-12, 2013

Town and Country Resort & Convention Center
San Diego, California USA

SIAM Conference on

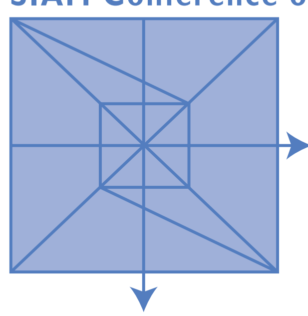

Figure courtesy Fabio Fagnani.

CONTROL & Its APPLICATIONS

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AN13 Abstracts

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IC1
Social Networks as Information Filters

Social networks, especially online social networks, are driven by information sharing. But just how much information sharing is influenced by social networks? A large-scale experiment measured the effect of the social network on the quantity and diversity of information being shared within Facebook. While strong ties were found to be individually more influential, collectively it is the weak ties that wield more influence and provide more diverse information exposure. This sharing behavior not only generates large cascades, but can also cause information to evolve. Joint speaker with the SIAM Workshop on Network Science.

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IC2
Cost-Minimizing Regulations for a Wholesale Electricity Market

We consider a wholesale electricity market model with generators interacting strategically and general networks including externalities such as transmission losses. Previous work shows how mechanisms such as the case when prices correspond to the Lagrange multipliers of a centralized cost minimization program allow the producers to charge significantly more than marginal price. This situation originates a important regulatory problem. In this presentation we consider an incomplete information setting where the cost structure of a producer is unknown to both its competitor and the regulator. We derive an optimal regulation mechanism and compare its performance to the "price equal to Lagrange multiplier".

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IC3
Keeping Ford Green with Mathematics

Scientific societies, universities, research institutes, and foundations all over the world have banded together to dedicate 2013 as a special year for the Mathematics of Planet Earth. In line with this theme, I will describe how Ford's strategic sustainability efforts, as outlined in the Blueprint for Sustainability, are supported by mathematical models. I will present examples of these modeling efforts, such as constructing global energy models, defining CO2 targets over time, helping fleet customers reduce CO2 emissions, and developing a future product and technology portfolio that reduces emissions. Ford is committed to employing sustainable business processes and developing sustainable products: it's not easy being green, but mathematics sure helps!

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IC4
Traffic Jams of Self-driven Particles

Jamming phenomena are seen in various transportation system including cars, buses, pedestrians, ants and molecular motors, which are considered as "self-driven particles". We recently call this interdisciplinary research on jamming of self-driven particles as "jamology". This is based on mathematical physics, and and includes engineering applications as well. In the talk, starting from the backgroud of this research, simple mathematical models, such as the asymmetric simple exclusion process and the Burgers equation, are introduced as basis of all kinds of traffic flow. Then it is extended in order to account various traffic phenomena, and the comparison between theory and experiment is given to show that the models are able to capture fundamental features of observations.

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IC5
Stochastic Multiscale Modeling

We consider systems that are governed by stochastic ordinary and partial differential equations (SODEs and SPDEs), and we will present some effective methods for obtaining stochastic solutions. These can be coarse-grained molecular systems exhibiting multi-rate dynamics and governed by a very large number of SODEs or continuum multiscale systems governed by SPDEs. We will present methods derived from the Mori-Zwanzig framework combined with PDF evolution equations as well as recent extensions of generalized polynomial chaos in high dimensions. We will also discuss various applications in biophysics and in mesoscopic materials.

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IC6
The Mathematics of Conservation Decision Making

Species are currently becoming extinct at least 100 times the background rate. The resources available to save biodiversity are inadequate. Consequently we need to optimise the return on investment from conservation decisions. In this talk I will show how we have been using optimisation tools to solve conservation problems such as reserve system design and allocating funds to threatened species management.

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IC7
Nonlinear Waves and Patterns: Two Examples

Nonlinear waves and patterns are ubiquitous in nature. Surface waves on rivers, lakes and oceans, cloud patterns in the air, crystal structures in materials and animal skin patterns are just a few examples encountered in our everyday lives. The underlying mathematical problems lead to nonlinear systems involving ordinary differential equations or partial differential equations. This talk focuses on the analysis of two kinds of nonlinear waves and patterns. Relying upon techniques from the areas of dynamical systems and bifurcation theory, we shall discuss, on the one hand the dynamics of nonlinear water waves, and on the other hand, the existence of defects, such as dislocations and grain boundaries, in pattern forming systems.

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IC8
Orthogonal Polynomials and Cubature Rules

Gaussian quadrature rules are important tools for numerical integration. Their nodes are necessarily zeros of orthogonal polynomials. Does this relation extend to cubature (synonym for quadrature in higher dimension) rules and orthogonal polynomials in several variables? The extension works in some extend, but the relation becomes far more complicated in higher dimension. For starter, it is necessary to consider common zeros of a family of polynomials, or, variety of a polynomial idea, in the language of algebraic geometry. This talk explains what is known about zeros of orthogonal polynomials and cubature rules, mostly restricted to two variables, and it includes several recent examples that provide efficient numerical integration rules.

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IC9
Photoacoustic Tomography: Ultrasonically Breaking through Optical Diffusion and Diffraction Limits

Photoacoustic tomography (PAT), combining optical and ultrasonic waves via the photoacoustic effect, provides in vivo multiscale non-ionizing functional and molecular imaging. PAT is the only modality capable of imaging across the length scales of organelles, cells, tissues, and organs with consistent contrast. PAT has the potential to empower multiscale systems biology and accelerate translation from microscopic laboratory discoveries to macroscopic clinical practice. PAT may also hold the key to the earliest detection of cancer by in vivo label-free quantification of hypermetabolism, the quintessential hallmark of cancer. The basic principle of PAT and the recent progress will be covered.

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IC10
Dynamics of Near Parallel Vortex Filaments

Techniques have been developed for the phase space analysis of the dynamics of many model nonlinear Hamiltonian PDEs. In this talk I will describe some extensions of these ideas to a problem in fluid dynamics concerning the interaction of two near-parallel vortex filaments in three dimensions. In addition, as well as generalizations of this problem, I will describe a number of promising further applications of the techniques of Hamiltonian PDEs and nonlinear evolution problems to other systems in fluid dynamics of physical significance.

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IP1
Likelihood-based Climate Model Evaluation

Climate models can be evaluated by comparing their output to observations. Remote sensing data provide new possibilities for such comparisons because they are spatially and temporally dense enough to go beyond simple moments and estimate distributions. We evaluate climate model fidelity to observations by the likelihood that a summary statistic computed from an observational time series arises from a sampling distribution of that same statistic calculated from a given climate model's time series. We demonstrate using models from the CMIP5 archive and observations from NASA's Atmospheric Infrared Sounder mission.

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IP2
Correlation and Causality

While everyone knows Berkeleys 1710 dictum correlation does not imply causation few realize that the converse causation does not imply correlation is also true. This conundrum runs counter to deeply ingrained heuristic thinking that is at the basis of modern science. Ecosystems are particularly perverse on this issue by exhibiting mirage correlations that can continually cause us to rethink relationships we thought we understood. Identifying causal networks is important for effective policy and management recommendations on climate, epidemiology, financial regulation, and much else. Here we introduce a method based on Takens theorem that can distinguish causality from correlation in dynamical systems. It is a radically different empirical approach for leveraging time series information from complex systems of interacting parts.

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IP3
AMS Invited Presentation: On the Geometry and Complexity of Solving Systems of Polynomial Equations

Theoretical computer science has a well developed notion of complexity. Numerical analysis doesn't have a comparably developed theory. In this context Steve Smale included in his list of problems for the next century: Problem 17: Solving Polynomial Equations. Can a zero of n-complex polynomial equations in n-unknowns be found approximately, on the average, in polynomial time with a uniform algorithm? I will describe progress on this problem including the eigenvalue problem (the answer looks like yes), and the mathematics employed.

Michael Shub

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IP4
Short-Term Renewable Energy Forecasting: Current Status, Challenges and Opportunities

The cost of integrating power from variable renewable energy sources such as wind and solar into electric systems is strongly linked to the accuracy of short-term (0-48 hours) predictions. Although forecasts from current approaches are providing considerable value, they often fail to anticipate critical events in which the energy resource experiences large and rapid changes. The presentation will provide an overview of the current status of renewable energy forecasting tools and performance, the key challenges that must be addressed to increase the value of forecasts and the near-term opportunities associated with new atmospheric sensor and modeling technology.

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IP5
The Search for a Human Fingerprint in the Changing Thermal Structure of the Atmosphere

Satellite temperature measurements reveal multi-decadal tropospheric warming and stratospheric cooling, punctuated by short-term volcanic signals of reverse sign. Similar long- and short-term temperature signals occur in model simulations driven by human-caused changes in atmospheric composition and natural variations in volcanic aerosols. Previous research attempted to discriminate a human-caused latitude/altitude pattern of atmospheric temperature change (”fingerprint”) from the background noise of internal variability. We present the first evidence that a human fingerprint can also be identified relative to the larger ”total” noise arising from internal variability, solar irradiance changes, and volcanic forcing.

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SP1
AWM-SIAM Sonia Kovalevsky Lecture: Introduction to Radar Imaging

Radar imaging is a technology that has been developed, very successfully, within the engineering community during the last 50 years. Radar systems on satellites now make beautiful images of regions of our earth and of other planets such as Venus. One of the key components of this impressive technology is mathematics, and many of the open problems are mathematical ones. This lecture will explain, from first principles, some of the basics of radar and the mathematics involved in producing high-resolution radar images.

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SP2
The John von Neumann Lecture: What Sparsity and l1 Optimization Can Do For You

Sparsity and compressive sensing have had a tremendous impact in science, technology, medicine, imaging, machine learning and now, in solving multiscale problems in applied partial differential equations. l1 and related optimization solvers are a key tool in this area. The special nature of this functional allows for very fast solvers: l1 actually forgives and forgets errors in Bregman iterative methods. I will describe simple, fast algorithms and new applications ranging from sparse dynamics for PDE, new regularization paths for logistic regression and support vector machine to optimal data collection and hyperspectral image processing.

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SP3
Past President’s Address: Chebfun

Chebfun is a Matlab-based open-source software project for “numerical computing with functions” based on algorithms related to Chebyshev polynomials. In recent years developing Chebfun has been my main research activity, together with the closely linked project of writing the book *Approximation Theory and Approximation Practice* (SIAM 2013). This talk will present some highlights of the Chebfun endeavor and will be followed by a two-part Chebfun minisymposium.

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SP4
W. T. and Idalia Reid Prize in Mathematics Lecture: Solvability for Stochastic Control Problems

Some stochastic control problems for continuous time systems are described where optimal controls and optimal costs can be explicitly determined by a direct method. The applicability of this method is demonstrated by examples including the linear quadratic control problem with the system driven by an arbitrary noise process with continuous sample paths, a controlled Brownian motion in a symmetric space and the linear exponential quadratic Gaussian control problem. The problems for linear systems can be modified to allow for equations in an infinite dimensional Hilbert space that describe stochastic partial differential equations.

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SP5
I. E. Block Community Lecture: From Razor Clams to Robots: The Mathematics Behind Biologically Inspired Design

Many natural systems have evolved to perform certain tasks – climbing, sensing, swimming – as perfectly as possible within the limits set by the laws of physics. This observation can be used both to guide engineering design, and to gain insights into the form and function of biological systems. In this talk we will consider both of these themes in the context of crawling snails, digging clams and swimming microorganisms. We will discover how an analysis of the physical principles exploited by snails and clams leads to the development of novel robotic diggers and crawlers, and explore the role of mathematics in the design, control, and assessment of unconventional robotic systems.

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SP6

James H. Wilkinson Prize Lecture: Interpolative Decomposition and Novel Operator Factorizations

I will discuss some recent results on developing new factorizations for matrices obtained from discretizing differential and integral operators. A common ingredient of these new factorizations is the interpolative decomposition for numerically low-rank matrices. As we shall see, these factorizations offer efficient algorithms for applying and inverting these operators. This is a joint work with Kenneth Ho.

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JP1

Applied and Computational Mathematics for Energy Efficient Systems

Recent advances in the development of sustainable energy sources have led to an emphasis on energy-supply technologies and the corresponding mathematical sciences needed for these technologies. However, energy efficient end-use technologies may also be viewed as an energy resource. Since buildings are responsible for 32% of energy consumption and for 26% of end-use C02 emissions, optimizing the efficiency of a whole building system is a "grand challenge control" problem with huge payoffs in the global energy sector. We discuss mathematical challenges and opportunities that occur in designing practical controllers for energy efficient buildings. Examples are presented to illustrate the ideas.

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CP1

On the Robust Stability of the Hill Equation with a Delay Term: A Frequency-Domain Approach

The paper considers the problem of robust stability of the Hill equation with a damping and a time-delay term. Analytical results are presented in terms of the coefficients of the equation. The derivation is based on the frequency-domain approach, specifically, the geometric interpretation of the Yakubovich stability criterion for linear time-periodic. There are two approaches to this interpretation: One involves analysis of the so-called Lipatov plots and the other is based directly on the Nyquist hodograph.

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CP1

Global Dynamics of SEIR Model with Holling Type II Incidence Function

The paper presents a model for the transmission dynamics of an arbitrary disease. The model, consisting of four mutually-exclusive compartments representing the human dynamics, has a globally-asymptotically stable disease-free equilibrium (DFE) whenever a certain epidemiological threshold, known as the basic *reproduction number* ($\mathcal{R}_\prime$) is less than unity, in such a case the endemic equilibrium does not exist. On the other hand, when the reproduction number is greater than unity, it is shown, using Nonlinear Lyapunov function theory and LaSalle Invariance Principle, that the unique endemic equilibrium of the model is globally-asymptotically stable under certain conditions. Furthermore, the disease is shown to be persistent whenever $\mathcal{R}_\prime > \infty$.

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CP1

A Robust Numerical Method for Solving Hiv-Malaria Co-Infection Model with a Distributed Delay

We construct a nonstandard finite difference method for the numerical solution of an HIV-malaria co-infection model with a distributed delay. Firstly, we analyze the continuous sub-models. Based on the qualitative properties of these models, we construct an efficient numerical technique. These qualitative properties are further used in measuring the competitiveness of our numerical method. Proposed method preserves some essential properties of the solution which are biologically relevant for the model.

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CP1

A New Class of Split Exponential Propagation Iterative Methods of Runge-Kutta Type (sEPIRK) for Semilinear Systems of ODEs

We propose a new class of exponential propagation iterative methods of Runge-Kutta (EPIRK) type specifically targeted for problems $y'(t) = Ly(t)+N(y(t))$ where the linear operator L is responsible for the stiffness of the system and $N(y(t))$ is the nonlinear remainder. Upon constructing specific schemes with desirable qualities, we then turn to numerical experiments. Through various test problems we will present comparative performance between these new EPIRK type methods and previously proposed EPIRK methods designed for the fully nonlinear right-hand-side function, $y'(t) = f(y(t))$.

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CP1

Exponential Splitting for Cocycles over Multivalued Non-Autonomous Dynamical Systems in Banach Spaces

As the state space of many dynamical systems that describe processes from engineering and physics is of infinite dimension, the approach is appropriate by means of associated operator families. Therefore, we introduce several notions of exponential splitting induced on Banach spaces by skew-evolution cocycles over multivalued non–autonomous dynamical systems, as well as various concepts of dichotomy. Characterizations for these notions and connections between them, underlined by examples and counterexamples, are also provided.

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CP1

Numerical Simulation of A Singularly Perturbed Harmonic Oscillator

A mass-spring system with a small mass forms a singularly perturbed damped harmonic oscillator. In a short time period, the spring oscillates rapidly and displays a boundary layer because of the small mass. Then the oscillation becomes smooth and it can be approximated in the absence of the small mass. An adaptive piece-wise uniform numerical simulation scheme is proposed. The accuracy is achieved at a high level with a constant mesh points for a family of singularly perturbed harmonic oscillators.

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CP2

Randomized Dimensionality Reduction in Machine Learning

We show how certain random sampling and random projections methods can be used to design efficient dimensionality reduction techniques for three popular machine learning problems: (i) K-means Clustering, (ii) Canonical Correlation Analysis, (iii) Support Vector Machine Classification. In all cases, we argue that randomized dimensionality reduction is provably efficient.

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CP2

Classification and Recognition of Light Scattering Patterns from Airborne Particles

TAOS is an experimental technique which collects the intensity pattern of LASER light scattered by a single, airborne material particle, $\approx 1\mu$m in size. An algorithm based on feature extraction and linear classification has been developed and implemented in two stages. In stage one the classifier is trained and validated by different sets of patterns from reference materials. In stage two the trained classifier is applied to patterns from bacterial spores and environmental sampling: pattern recognition occurs by information fusion. A large data set ($> 5,000$ patterns) has been analysed. *Bacillus subtilis* patterns are discriminated from those of other materials. Progress will be reported in the classification of patterns from outdoor sampling and from confounder materials.

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CP2

Determining Number of Motifs in Wind Generation Time Series Data

It is a challenge to schedule wind energy on the power grid especially when forecasts are inaccurate. Using techniques from time series analysis, we show how motifs, or frequently occurring diurnal patterns, in wind generation data can be used to guide scheduling decisions. We discuss how quality analysis can be applied to determine the number of motifs that exist in data from wind farms in Tehachapi Pass and mid-Columbia Basin.

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CP2

Convergence and Stability of the Split-Step θ-Milstein Method for Stochastic Delay Differential Equations

A new splitting method designed for the numerical solutions of a kind of stochastic delay differential equations is introduced and analysed. Under Lipschitz and linear growth conditions, this split-step θ-Milstein method is proved to have a strong convergence of order 1 in mean-square sense, which is higher than that of existing split-step θ-method. Further, mean-square stability of the proposed method is investigated. Numerical experiments and comparisons with existing methods illustrate the computational efficiency of our method.

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CP2

An Integrated ANN Approach to Identify the Types of Disturbances for An SPC/EPC System

Autocorrelation often results in an increased rate of false alarms for typical statistical process control (SPC) charts. To overcome this difficulty, the engineering process control (EPC) is employed to compensate for the effects of autocorrelation. However, because of the over-control problem of EPC, it becomes much more difficult to identify the types of underlying process disturbances. We propose an artificial neural network (ANN) approach to effectively identify the types of disturbances for a SPC/EPC system.

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CP2

A Deeper Look at the ℓ^1-Graph

We aim to improve current methods of graph construction for use in dimensionality reduction, clustering, and label propagation. In particular, we study Cheng, et al.'s "ℓ^1-graph.' This method simultaneously computes the graph structure and edge weights by decomposing each data point as a linear combination of the remaining samples so that the ℓ^1-norm of the coefficients is minimized. We seek further theoretical justification for the ℓ^1-graph's experimental success, as well as improvements to this method through the framework of block sparsity. Additionally, we aim to utilize the structure of the dual polytope associated with the overcomplete data dictionary to reduce the construction complexity via "warm-starting' several of the numerous ℓ^1-minimization problems that must be solved. Time permitting, we will also discuss the structure of the produced graph.

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CP3

Efficient Asymptotic Preserving Schemes for Higly Anisotropic Ellitpic Problems, Application to the Simulation of the Ionospheric Plasma Disturbances

An Asymptotic-Preserving scheme is introduced for the approximation of singularly perturbed anisotropic elliptic equations. This numerical method is designed to offer an efficiency, with respect to both the precision and the numerical cost, independent of the anisotropy strength. A class of anisotropic elliptic problems occurring in the simulation of magnetized plasma and more specifically ionospheric plasma disturbances, is addressed to illustrate the capabilities of the AP-scheme.

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CP3

Phase Change at the Nanoscale

Nanoparticles have generated tremendous interest in the scientific community in the last few decades: they exhibit unique optical, electrical, and magnetic properties not seen at the bulk scale. These properties and their size make them attractive for industrial and biomedical applications. One form of application, based on the melting process of nanoparticles, is used in drug delivery or microelectronics. In this talk, we present a mathematical model describing the melting of nanoparticles that takes into account the Gibbs-Thomson effect and the thermal expansion of the nanoparticles, which turn out to be no-negligible at that scale. The melting times obtained from our results are in good agreement with experimental observations.

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CP3

Virtual Nuclear Reactor Modeling Using Lime

The Lightweight Integrating Multiphysics Environment library (LIME) is built as an extension to the Trilinos solver framework to enable generalized multiphysics code coupling. LIME's coupling algorithms span fixed-point coupling, placing no restrictions on models or methods, through Newton-based coupling, requiring residuals from participating codes. This talk will present enhancements to fixed-point based coupling applied to nuclear reactor performance modeling. These enhancements represent various types of acceleration or mixing methods applied within a hierarchical multiphysics problem.

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CP3

Upscaling of Microscale Reactive Transport to the Darcy Scale

We have developed a subsurface simulation capability to resolve pore scale processes at the microscopic scale (¡ 10 microns) on a continuum scale domain (1 meter). The pore scale data can be upscaled to the continuum scale to obtain heterogeneous values of permeability and reaction rates. For example, we use a combination of flux weighted averaging for the velocity and the divergence theorem for gradient of pressure to obtain a permeability value from a local pore scale patch that is equivalent to a representative elemental volume for the Darcy equations. We also discuss an adaptive modeling technique for fully coupling the microscopic and macroscopic equations with an AMR framework where the continuum model is refined to a pore scale model only in local areas of interest in the domain.

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CP4

Radial Basis Function (RBF) Approximation Is Indistinguishable From Hermite Function Interpolation on a Finite Interval: RBFs Without Matrix Inversion

On a uniform grid, very accurate approximations to Gaussian RBF cardinal functions can be constructed by multiplying polynomial cardinal functions by a Gaussian. Using the Gaussian-times-polynomial basis gives approximations to a smooth function $f(x)$ which are as accurate as those of radial basis functions. The new basis is equivalent to approximation on a finite interval by Hermite functions. Matrix inversion and the contour Pade and RBF-QR algorithms are unnecessary.

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CP4

Perturbation of *-Derivations on Fuzzy Banach *-Algebras

Let A be a Banach $*$-algebra. A linear mapping $\delta : A \to A$ is said to be a $*$-*derivation* on A if $\delta(ab) = \delta(a)b + a\delta(b)$ for all $a, b \in A$ and $\delta(a^*) = \delta(a)^*$ for all $a \in A$. Every bounded $*$-derivation δ on a C^*-algebra arises as an infinitesimal generator of a dynamical system for R. For several reasons the theory of bounded derivations of C^*-algebras is important in the quantumn mechanics. We establish the functional equations of $*$-derivation induced by the Cauchy equation and the Jensen equation, respectively. And we also prove the stability of derivations on fuzzy Banach $*$-algebras and also prove the superstability of derivations.

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CP4

N Masses on a String

One-dimensional time-harmonic waves interact with N identical scatterers. We solve this classical problem using transfer matrices. For a row of N equally spaced scatterers, the reflection and transmission coefficients can be calculated explicitly, using Chebyshev polynomials. Here, the emphasis is placed on problems where the scatterers are perturbed from their equispaced positions. Explicit results are obtained. They are useful in understanding the construction of effective media for one-dimensional random media.

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CP4

On a Representation of Functions of Several Variables As Superposition of Functions of One Variable and Addition by Using An Algebraic Identity

A theorem is given for representing functions of many variables as superposition of differentiable functions of one variable and addition through the use of an algebraic identity that rewrites a product of n variables as additions of nth power functions. The relations between this theorem and Kolmogorov's superposition theorem are discussed. Besides, an application of this theorem to piecewise linear function approximation for a non linear function having more than two variables-multiplication terms, is introduced.

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CP5

Solving Composite Minimization and Its Application to Image Deblurring

We study the following composite minimization problem

$$\min\{f(\mathcal{A}\S), \S \in \mathcal{R}^\backslash\}, \tag{1}$$

where $\mathcal{A}$ is a matrix and the function f is proper, lower semi-continuous, convex but not necessarily differentiable. This problem covers a large range of problems in image processing, i.e., denoising, deblurring, inpainting. An iterative algorithm is proposed to solve the composite minimization problem. Further if the function is separable, an accelerated variant algorithm is proposed. Each step in the iterate has closed form and therefore can be efficiently implemented . Also, convergence of the algorithms can be guaranteed understand certain conditions. Finally, we apply the proposed algorithms to solve the L2-TV and L1-TV deblurring problems. Numerical results show that the proposed iterative procedures can outperform some state-of-art algorithm in terms of CPU time and PSNR.

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CP5

From Proteins to Cells; Progress in Large Field Electron Microscope Tomography

In combination with other techniques electron tomography can provide three dimensional reconstructions of protein assemblies, correlate 3D structures with functional investigations at the light microscope level and provide structural information which extends the findings of genomics and molecular biology. Because of rapid advances in instrumentation and computer-based reconstruction, the routine imaging of molecular structure in context appears to be likely within the next few years. We will discuss the inversion of the generalized Radon transform which appears in the context of EM tomography.

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CP5

Repulsive Random Walk in Automatic Number Plate Recognition

The Repulsive Random Walk is an exploration algoritm based on particle swarm models and random walks. The interaction between the particles and the space formed by an image are used to detect license plates as part ANPR system, through which a sample may be obtained properties of the image elements. The results indicate that it is a viable method for scanning images.

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CP5

Estimating the Optimal Truncated SVD Filter for Image Restoration

Image restoration is a challenging inverse problem for which solutions involving filters have been proposed. In this work we use statistical analysis and observed properties of the noise to estimate the optimal parameter for the truncated SVD filter. The resulting restorations for several test images compare favorably to those using parameters estimated through generalized cross-validation (GCV) and the discrepancy principle and are not much different from restorations using the true (generally unknown) optimal parameter.

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CP5

Medical Imaging Via Slim

Iterative reconstruction (IR) algorithms have attracted significant attention in the medical imaging area for their improved image quality while reducing the radiation dose in CT X-ray imaging, at the cost of significantly increased computational complexity. We propose to use the SLIM algorithm, for the medical image reconstruction. SLIM is a sparse signal recovery algorithm that has excellent interference/noise suppression and high resolution properties. The most attracting property of SLIM is that it can be implemented very efficiently by using the conjugate gradient (CG) and the fast Fourier transform (FFT). The computational complexity will be evaluated by comparing with the benchmarks of the available IR algorithms.

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CP5

Synchrosqueezed Wave Packet Transform for 2D Mode Decomposition

This paper introduces the synchrosqueezed wave packet transform as a method for analyzing 2D images. This transform is a combination of wave packet transforms of a certain geometric scaling, a reallocation technique for sharpening phase space representation, and clustering algorithms for mode decomposition. For a function that is a superposition of several wave-like components satisfying certain separation conditions, we prove that the synchrosqueezed wave packet transform identifies these components and estimates their instantaneous wavevectors. A discrete version of this transform is discussed in detail and numerical results are given to demonstrate properties of the proposed transform.

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CP6

Ritz-Galerkin Isogeometrics and Transformation Optics to Describe Metasolenoid Electromagnetic Singularities

This is a continuation of the invisibility-cloaking research presented at the Society for Industrial and Applied Mathematics (SIAM) Conference on Partial Differential Equations November 14, 2011. Principles of finite element analysis, isogeometrics and transformation optics will be used to develop a model of a perfectly lensing metasolenoid. The conjecture is that fields at microwave frequencies are distorted and electromagnetic black hole singularities will be formed at the boundaries (Ikonen et. al 2005). The Ritz-Galerkin Method and iosgeoemtric analysis will be used to evaluate PDEs for the Helmholtz electromagnetic equations, as well as General Relativity applied to optics and electromagnetism. Implications include no loss wireless antenna metasolenoids, cloaking and electromagnetic black hole research, and possible applications in string theory to describe quantum effects in EM black holes.

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CP6
Electromagnetic XFEM with Weak Discontinuities

In electromagnetic multimaterial problems, surface effects are critical, as current tends to concentrate on material surfaces, Lagrangian meshes are often untenable due to large deformations, leaving Eulerian meshes with a mixture model as the only option. We present an alternative edge element extended finite element method based on a tied Heaviside approach. We prove its equivalence to a body-fit finite element problem and demonstrate that it retains the expected order of convergence.

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CP6
Optimum Experimental Design for Egdm Modeled Organic Semiconductor Devices

We apply optimum experimental design (OED) to organic semiconductors modeled by the extended Gaussian disorder model (EGDM), see [Pasveer et al., 2005]. We present an algorithm based on Gummel's method coupled with Newton's method. Automatic differentiation is used to get derivatives with the required accuracy for OED. We show that the linearized confidence regions of the mobility parameters can be reduced significantly by OED, resulting in new experiments with a different setup.

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CP7
Randomized Matrix Algorithms for Spectral Clustering

Spectral clustering is a class of methods to solve problems in the fields of machine learning, pattern recognition and image and mesh processing. They are related or based on eigenvalues, eigenvectors or eigenspace projections derived from very large and dense affinity matrices. Eigenproblems associated with the Normalized k-Cut will here exemplify that randomized matrix techniques are particularly suitable for such computations. Additionally we show how useful information can be extracted directly from the affinity matrix.

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CP7
New Results on the Kogbetliantz Method

The Kogbetliantz method is an important tool for computing the singular value decomposition (SVD) of triangular matrices. It preserves almost diagonality and triangularity of the starting matrix and is nicely suited for subspace tracking problem. It can serve as the core algorithm of block Jacobi methods for the SVD problem of dense matrices using CPU and GPU computations. All known properties and the new relative accuracy results of the method will be presented.

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CP7
A Paradigm of Complex Symmetric Matrices in Matrix Analysis

A huge expansion of matrix analysis is achieved for non-defective nonsingular complex symmetric matrices as a new paradigm especially for physically realizable systems. Those matrices describe systems with periodic excitations not included in prior matrix analysis. They are also complex definite and diagonalizable by either complex orthogonal similarity or unitary consimilarity. Another paradigm includes well-known Hermitian matrices existing in physical systems with random excitations. Symmetry is a critical factor to understand interwoven theories including consimilarity.

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CP8
Partial Differential Equations Practicum

In this Partial Differential Equations (PDEs) practicum, we show practical and quick tools for solving linear and nonlinear PDEs. More specifically, we help you find analytic solutions to linear PDEs; first order linear and nonlinear PDEs; and higher order nonlinear PDEs. Navier-Stokes, Black-Scholes, Vlasov-Maxwell, Schrodinger, Poisson, Wave are just some of the PDEs you can solve. Steve Anglin, Sc.M., Ph.D. (h.c.) of http://facebook.com/Diffequations is a mathematical engineer and former Case lecturer.

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CP8
Image-Driven Inverse Problem for Estimating Initial Distribution of Brain Tumor Modeled by

Advection-Diffusion-Reaction Equation

We present results for solving an image-driven inverse problem of brain tumor growth. Our objective is to reconstruct initial distribution of the tumor in the patient's brain. Tumor growth is modeled as an advection-diffusion-reaction equation which is coupled to an elasticity equation modeling parenchyma deformation. Our inversion algorithm is an adjoint-based Newton scheme that requires efficient evaluation and inversion of Hessian operator. We will present problem formulation, our novel numerical scheme, and results on a clinical dataset.

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CP8

Wave of Chaos and Pattern Formation in Spatially Extended Three Species Model Systems

The complex dynamics of two types of tri-trophic food chain model systems, modeling two real situations of marine ecosystem, are investigated in this study. The study has been carried out with the objective to explore and compare the competitive effects of fish and molluscs species being the top predator, when phytoplankton and zooplankton species are undergoing spatial movements in the subsurface water. Wave of Chaos mechanism is found to be the responsible factor for the pattern formation in one dimension seen in the food chain ending with top generalist predator. In the present work, WOC phenomenon is reported for the first time in literature, in a three species spatially extended food chain model system. An ecosystem having top predator as specialist leads to the stability of the system.

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CP8

Mathematical Modeling and Simulation of Biofilm Dispersal

Biofilm is the community of microorganism which are encased in an extracellular polymeric matrix. The bacterial cells engage in a cell-cell communication called quorum sensing with which they coordinate their behaviour. Bacterial cells can disperse from the biofilm into the aqueous phase. We study the mathematical model of biofilm dispersal with the underlaying mechanisms of quorum sensing leading to a system of partial differential equation. We investigate the magnitude and timing of the cell dispersal.

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CP9

Nonlinear Gerschgorin Regions and Applications

We consider an extension of Gerschgorin's theorem to nonlinear eigenvalue problems $T(z)v = 0$, where $T(z) = A - zI + E(z)$ is a matrix-valued function that is analytic over some simply connected domain in the complex plane. As with the conventional Gerschgorin circle theorem for the linear eigenvalue problem, this nonlinear Gerschgorin theorem is a useful tool for deriving other eigenvalue localization problems, such as a nonlinear variant of the Bauer-Fike theorem.

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CP9

A Non-Gap-Revealing Method for Determining Numerical Rank

The rank revealing problem arises widely in scientific computing and engineering applications, such as signal processing, information retrieval, numerical polynomial algebra, and so on. Some of those applications give rise to a large matrix whose rank or nullity is known to be small apriori. Several methods have been proposed for this purpose. In general, they compute a gap-revealing factorization for estimating the singular values. In this talk, we will present a rank-revealing method to deal with large matrices with low ranks/low nullities by constructing an orthonormal basis for the subspace of the matrix directly.

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CP9

Similarity Reduction to Upper Hessenberg Form

Input your abstract, including TeX commands, here. Alternatives previously devised for stable similarity reduction of real nonsymmetric matrices to low bandwidth Hessenberg form rely on bounded gaussian transformations applied to successive matrix rows and columns. Interaction of large multipliers limit magnitudes allowed for stablitiy. The new QG algorithm relies primarily on orthogonal (Householder) transformations with at most one nonzero element in each row eliminated with a bounded gaussian transformation. This doubles the flops but leads to less interaction, thus allowing larger multipliers which yield smaller bandwidths.

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CP9

A Linear Complexity Structured Selected Inversion for Large Sparse Matrices

We propose a structured method for extracting the diagonal of a sparse matrix, using the multifrontal method and rank structured matrices. The method has nearly $O(n)$ complexity for some 2D and 3D problems, after the structured factorization of about $O(n)$ and $O(n^{4/3})$ flops, re-

spectively, where n is the size of the matrix. The memory requirement is also about $O(n)$. In comparison, existing inversion methods cost $O(n^{1.5})$ in 2D and $O(n^2)$ in 3D, with $O(n \log n)$ and $O(n^{4/3})$ memory, respectively. Also, our method can quickly extract an arbitrary entry of the inverse in about $O(1)$ to $O(log^2 n)$ flops, due to the data sparsity.

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CP10

Optimal Error Analysis of Linearized Backward Euler Galerkin Fems for Time-Dependent Nonlinear Joule Heating Equations

We study two linearized backward Euler schemes with Galerkin finite element approximations for the time-dependent nonlinear Joule heating equations. By introducing a time-discrete system as proposed in [LI & Sun, Error analysis of linearized semi-implicit Galerkin finite element methods for nonlinear parabolic equations, *Int. J. Numer. Anal. & Modeling*, 10 (2013), 622-633.], we present unconditionally optimal error estimates of r-th order Galerkin FEMs ($1 \leq r \leq 3$).

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CP10

Combined Finite-Element, Finite-Volume, and Discrete Event Simulation of Structurally Complex Hydrocarbon Reservoirs

Multiphase flow processes accompanying the production of structurally complex hydrocarbon reservoirs occur on vastly different time- and length scales. This impacts reservoir simulation to date because global time-stepping strategies are still used. Creation of a direct or indirect dependence on the CFL condition is unavoidable and particularly restrictive when spatially adaptive gridding / flow-based upscaling is used so that small cells discretize zones of fast flow. To overcome such limitations, we apply an asynchronous time-stepping methodology called Discrete Event Simulation to model reservoir flow. Operator splitting is used for space discretisation, employing the FEM for parabolic PDE components and FVM for hyperbolic ones.

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CP10

Fourth-Order Mimetic Finite Difference Modeling of Free Surfaces on Elastic Media

In this work, we apply fourth-order mimetic finite differences to computationally simulate the wave pattern excited by a point source located along a flat free surface of a linearly elastic and isotropic half plane. The physical free surface boundary condition represents homogeneous linear equations satisfied by the traction vector components. This coupled system of differential equations, elastodynamics in the interior and Newmann-type boundary conditions, is discretized on a staggered grid using mimetic finite differences that provide both, central and lateral stencils, avoiding the location of grid points beyond the physical boundaries, and making our numerical implementations memory-saving.

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CP10

Gradient-Augmented Schemes for Reinitialization and Other Hamilton-Jacobi Equations

We demonstrate how the semi-Lagrangian "jet scheme' framework can be applied to solve certain Hamilton-Jacobi equations, such as the reinitialization equation that is popular in the context of level set methods. The resulting numerical approaches are high order accurate, with an optimally local update rule. Information is propagated correctly along characteristics, even in the presence of shocks.

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CP10

Chebyshev Collocation Methods for Hyperbolic Balance Laws with Non-Stationary Singular Source Terms

This work proposes the use of a class of piecewise polynomials compactly supported to approximate the Dirac delta distribution with the desired order of accuracy and smoothness, in the numerical solution of hyperbolic balance laws with this singular source term, using spectral methods. For spatial discretization is used the spectral Chebyshev collocation method with Gauss-Lobatto nodes and the third order total variation diminishing (TVD) Runge-Kutta scheme for time integration. The accuracy of the numerical scheme is analyzed for various choices of the support length, using an approximation to the Dirac delta with three vanishing moments (third order accurate) and two continuous derivatives. Numerical results supports the effectiveness of the proposed methodology, showing a convergence order according to the asymptotic behavior of the spectral interpolation error in the L^2_w and L^∞ norms.

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CP10

On the Numerical Integration of Initial-Boundary Value Problem to One Nonlinear Parabolic Equation

In the presented work the general initial-boundary value problem to the following nonlinear parabolic equation

$$\frac{\partial U}{\partial t} = a\left(x,t,U\right)\frac{\partial^2 U}{\partial x^2} + b\left(x,t,U\right)\left(\frac{\partial U}{\partial x}\right)^2 + f\left(x,t\right)$$

is considered. For the considered problem the equivalent initial-boundary value problem is obtained to which the difference scheme is constructed. For mentioned difference scheme the theorem of existence of its solution and the theorem of convergence of its solution to the solution of the source problem are proved under some restrictions on coefficients $a\left(x,t,U\right)$ and $b\left(x,t,U\right)$. The rate of convergence is established and it is equal to $O\left(\tau + h^2\right)$. The corresponding numerical experiments were conducted which confirmed the validity of the theorems.

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CP11

Numerical Evidence of Extreme Diffusive Stabilization in Immiscible Models of Chemical Enhanced Oil Recovery

The effect of diffusion of species in the Hele-Shaw model of chemical enhanced oil recovery on the hydrodynamic instability is numerically studied. We provide numerical evidence of remarkable stabilization of fluid flow instabilities when interfaces between fluid phases are treated as impermeable to species diffusion and concentrations of the species are in dilute regimes. This is consistent with a speculation made earlier by the author. Several new features of the numerical solutions are noted

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CP11

On the Stability of Perfectly Matched Layer for the Wave Equation in Heterogeneous and Layered Media

We will discuss the efficiency of the perfectly matched layer for the wave equation in heterogeneous and layered media. We prove the stability of the layer for discontinuous media with piecewise constant coefficients and derive energy estimates for discontinuous media with piecewise smooth coefficients. In order to ensure the stability of the discrete PML, the interface conditions are tranformed to include the auxiliary variables. Numerical experiments are presented demonstrating the stability and high order accuracy of the layer.

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CP11

Modeling Surface Currents in The Eastern Levantine Mediterranean

We consider the problem of reconstructing meso-scale features of the currents in the Levantine Mediterranean region by combining in-situ (floaters) and altimetry data. Lagrangian trajectories of the floaters are used to improve the coarse Eulerian field obtained by altimetry. The inverse problem is solved using a variational assimilation technique, whereby the velocity correction is obtained by minimizing the distance between a model solution and observations of the floaters position. This approach shall be validated with real data from the region.

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CP11

3D Underwater Acoustical Imaging with Contrast Source Inversion Technique

A non-linear inversion approach is presented for the acoustical imaging of 3D objects located in a water reservoir such as lake, ocean, etc. The space which is composed of air-water-soil layers is modelled as a three layered medium having rough surfaces at the air-water and water-soil interfaces. Through the Green's function of the background the problem is reduced to the solutions of two coupled system of non linear integral equations which are solved iteratively by the application contrast source inversion method. The Greens function of the layered media is calculated by the buried object approach. It is also accelerated through the method of discrete images. The method yields quite accurate results even with the incomplete data.

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CP12

A Mathematical Model for Eradication of the Screwworm Fly by Sterile Insect Release Method

The Sterile Insect Release Method is used to control invasive insect species by introducing large quantities of sterilized male insects into a wild population of invading insects. When fertile insects mate with sterile insects their offspring are not viable and wild insects may be eradicated. Motivated by a spatially symmetric sterile insect barrier that is characteristic of the screwworm fly eradication program, we consider a reaction-diffusion model of SIRM and analyze two spatially inhomogeneous steady-state solutions of this model. These steady states may result from an ineffective barrier (fertile flies are extant on both sides) or an effective barrier (fertile flies are extant on one side but extinct on the other). We determine the minimum effective barrier size.

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CP12

Mussel/Oyster Population Dynamics and Control

The Asian Green Mussel was found to be in competition with the resident Eastern Oyster shortly after its discovery as an invasive species in the Tampa Bay area. We model the population dynamics as a Lotka-Volterra type system of differential equations, with additional terms taking into account environmental conditions. Relative parameter values were estimated based on observations. A corresponding optimal control problem looks at using salt dumps to manage the mussel population.

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CP12

Periodicity of An Arizona Tiger Salamander Population

Arizona Tiger Salamanders exhibit facultative paedomorphosis in which salamander larvae either metamorphose into terrestrial adults or become sexually mature while still in their larval form. Although many salamanders exhibit cannibalism of larvae, the Arizona Tiger Salamander also exhibits cannibalism of young by the aquatic adults. We formulate an ODE model of this system, construct periodic solutions and compare them with existing data.

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CP12

Ant-Isocial Dynamics: Studying Ant Social Network Accumulation

Social network analysis is used to study animal interactions. Animal social networks analysis generally uses time-aggregated networks. Our approach differs because we analyze how interactions accumulate over time. Ant species *Formica subsericea* lives in large colonies and relies on interaction to share information. We compare how the interactions of different-sized groups of these ants accumulate over time using network statistics including, path length, average interactions per ant, clustering coefficient, and largest connected component size.

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CP12

A Stochastic Model for *Escherichia Coli* O157:H7 Infection in Cattle

Escherichia coli O157:H7 is an important foodborne pathogen with a natural reservoir in the cattle population. To understand the spread and persistence of the infection in cattle, we developed a stochastic model to study *E. coli* O157:H7 transmission in cattle. In this presentation, I will talk about the extinction and outbreak of infection by solving the Kolmogorov equations associated with statistics of the time to extinction and outbreak. The results provided insight into *E. coli* O157:H7 transmission and apparent extinction, and suggested ways for controlling the spread of infection in a cattle herd. Specifically, this study highlighted the importance of ambient temperature and sanitation, especially during summer.

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CP13

Noise Induced Oscillations and Coherent Stochastic Resonance in a Generic Model of the Non-isothermal Minimal Chemical Oscillator

Oscillating chemical reactions are common in biological systems and they also occur in artificial non-biological chemical systems. Generally, these systems are subject to random fluctuations in environmental conditions which translate into fluctuations in the values of some physical variables, for example, temperature. We formulate a mathematical model for a nonisothermal minimal chemical oscillator containing just a single negative feedback loop and study numerically the effects of stochastic thermal fluctuations in the absence of any deterministic limit cycle or periodic forcing. We show that thermal noise can induce sustained limit cycle oscillations with a relatively narrow frequency distribution and some characteristic frequency. These properties differ significantly depending on the nature of the noise correlation. Here, we have explored white and colored (correlated) noise. A plot of the characteristic frequency of the induced oscillations as a function of the correlation exponent shows a sharp maximum, therefore indicating the existence of coherent (autonomous) stochastic resonance.

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CP13

Surface Traction and the Dynamics of Elastics

Rods at Low Reynolds Number

The past forty years have witnessed an ever-increasing interest in applications of slender-body dynamics (such as Kirchhoff rod theory), in particular with regard to the shape, movement, or material parameters of biomolecules or materials. In most applications, hydrodynamic interactions (i.e. surface traction often approximated by resistive force theory) have been of utmost importance since the biologically relevant scales usually result in very small Reynolds number. However, the formulation of classical Kirchhoff slender-body assumes no surface traction in the development of the constitutive relation. We will discuss an asymptotic approach to reconciling this apparent inconsistency and provide velocity bounds for which the compatibility of Kirchhoff rod and resistive force theory hold.

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CP13

A Model for Transient Evolution of a Material with Complex Microstructure from Elastic Deformation to Flow

We consider a subclass of non-Newtonian materials which behave as solids at equilibrium, and flow only under sufficiently high stresses. At intermediate applied stresses, the material waits for a long time before flowing; for example, ketchup. The slow and fast time scales are interpreted in the light of a large relaxation time limit of a viscoelastic constitutive model for the microstructure, together with a solvent. Homogeneous unidirectional extension, given an instantaneous tensile stress, is addressed.

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CP13

Mathematical Modeling of Transverse Shear Deformation Thick Shell Theory

IIn this paper, the three dimensional elasticity theories in curvilinear coordinates of thick shells are discussed. The relationship between forces, moments and stresses are given and the equations of motion are derived using Newtons 2nd law of motion and Hamiltons principle. The necessary theoretical assumptions are discussed to reduce the three dimensional (3-D) elasticity to two-dimensional (2-D) shell theory of third order to a first order equation. Equilibrium equations are formulated using the equations of stress resultants to arrive at a system of differential equations and solved by Fourier expansion. The results are compared with the three- dimensional elasticity theory from existing literature.

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CP14

A Minimum Sobolev Norm Technique for the Numerical Solution of PDEs

We present a method for the numerical solution of PDEs based on finding solutions that minimize a certain Sobolev norm. Fairly standard compactness arguments establish convergence. The method prefers that the PDE is presented in first order form. A single short Octave code is used to solve problems that range from first-order Maxwell's equations to fourth-order bi-harmonic problems. The method is high-order convergent even on complex curved geometries.

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CP14

Application of Fft-Recursive-Relation Based Hybrid Fast Algorithms to Computing Interfacial Flows

This talk will be based on current work in progress on computing interfacial flows that makes use of fast algorithms developed by one of the authors (PD) in combination with front tracking and level set methods. Performance of these methods on such problems arising the context of chemical enhanced oil recovery will be presented.

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CP14

Hp Finite Element Method for Linear Dispersive Waves

Maxwells equations are a system of partial differential equations which model electromagnetism. Coupled with constitutive laws, they are of interest in simulating electromagnetic waves in various media. In this paper we focus primarily on Debye model which is a linear first order ordinary differential equation in time which models a simple relaxing dielectric. This model, called Maxwell-Debye is singularly perturbed and results in complex dispersive and diffusive wave behavior. This behavior is frequency dependent and stiff. Solving this problem numerically has applications to biomedical imaging and seabed mapping. Adapting the the work of Ainsworth, we proceed to produce bounds on the dispersion error of hp finite element methods for for the one dimensional Maxwell-Debye. This analysis suggests that neither h nor p adaptive finite elements will be sufficient to adequately reduce the dispersion error. A number of numerical simulations are presented as well.

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CP14

A Balancing Domain Decomposition Method by Constraints for Raviart-Thomas Vector Fields

A BDDC preconditioner for vector field problems discretized with Raviart-Thomas elements is introduced. Our method is based on a new type of weighted average developed to deal with more than one variable coefficient. A bound on the condition number is provided which is independent of the values and jumps of the coefficients and has a polylogarithmic bound in terms of the number of degrees of freedom of the individual subdomains.

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CP14

Semilinear Elliptic PDE on Manifolds

In this paper we begin by introducing the Closest Point Method (CPM) and the Gradient Newton Galerkin Algorithm (GNGA). We use GNGA to solve PDEs on manifolds by first finding eigenfunctions of the Laplacian restricted to the manifold using the CPM. Finally we use a Galerkin expansion in eigenfunctions of the Laplacian, to find the desired solutions. In this paper we extend the theoretical underpinnings of GNGA to solving the desire PDE on manifolds. This extended method combined with utilizing the CPM to generate the needed eigenfunctions allows us to compute on manifolds with relative ease. In this paper we present several examples on basic manifolds which do not require the CPM calculation, followed by more interesting examples where CPM is necessary.

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CP15

Symmetry-Breaking Hopf Bifurcations to 1-, 2-, and 3-Tori in Small-Aspect-Ratio Counter-Rotating Taylor-Couette Flow

Nonlinear dynamics in differentially counter-rotating cylinders is investigated by solving the full three-dimensional Navier-Stokes equations. Dynamics are dominated by the jet of angular momentum emerging from the inner cylinder boundary layer at about the mid-plane. The sequence of bifurcations consists of an axisymmetric Hopf bifurcation breaking the reflection symmetry of the basic state leading to an axisymmetric limit cycle with a half-period-flip spatio-temporal symmetry. This undergoes a Hopf bifurcation breaking axisymmetry, leading to quasi-periodic solutions evolving on a 2-torus that is only half-period-flip symmetric due to precesion. A further Hopf bifurcation introducing a third incommensurate frequency leading to a 3-torus on that a saddle-node-on-an-invariant-circle (SNIC) bifurcation takes place, destroying the 3-torus and leaving a pair of symmetrically-related 2-tori states on which all symmetries of the system have been broken.

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CP15

Simulating Three-Dimensional Fluid Flow in Porous Media

Numerically modeling fluid flow through explicit porous media is computationally demanding. However, fluid flow through samples of explicit pore spaces can be simulated efficiently, while reproducing key physics of percolating flows, by combining non-oscillatory (viz. high-resolution) Navier-Stokes integrators with semi-implicit representation of elementary (i.e., first-order) immersed-boundary forcing. Here, fluid flow is allowed to reach steady state in a given porous medium, and the resulting velocity and pressure fields are analyzed. We compute attributes of particle trajectories including tortuosity, trajectory length, and first passage percolation time. The fluid velocity fields become more homogeneous with increasing porosity indicated by a decrease in the variance of tortuosity, trajectory length, and travel time distributions.

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CP15

Uncoupling Groundwater-Surface Water Flow Using Partitioned and Multi-Rate Methods

Partitioned methods for the evolutionary Stokes-Darcy equations uncouple the system so that at each time step we solve separate ground- and surface water problems using codes optimized for the physics in each sub-domain. Challenges include maintaining stability and accuracy along the interface and when given small parameters. We adapt partitioned methods to obtain multi-rate splitting methods. This is advantageous since flow in aquifers with low conductivity moves slowly, requiring accurate calculations over long time periods.

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CP15

Turbulent Fluid Mixing of Multiphase Flow

We develop an interface tracking simulation for predicting interaction of droplets in rotating flows relevant to optimized design of centrifugal contactor devices used in solvent extraction processing and other separation operations. We study the turbulent Taylor-Couette flow mixing of a two-phase (organic and aqueous) mixture in a centrifugal contactor. We find extensive fluid mixing and an enhanced interfacial area for chemical reactions to occur at the interface between the two phases.

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CP15

Onset of Buoyancy-driven Convection in Cartesian and Cylindrical Geometries

We perform a linear stability analysis to examine the onset of buoyancy-driven convection relevant to subsurface carbon dioxide injection in confined, porous Cartesian and cylindrical domains. The lateral boundaries impede the onset. The patterns of the most unstable perturbation mode in Cartesian and cylindrical domains are highly different, and we hypothesize that this may eventually lead to different behavior in the two geometries. Our results may guide future numerical studies that can investigate this hypothesis.

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CP16

The Effects of Numerical Model Error on 4D-Variational Data Assimilation

4D-Variational data assimilation is typically used for forecasting physical systems. It finds an initial condition for a numerical model, by combining observations with predictions. The numerical model is then used to produce a forecast. Numerical model error affects the accuracy of the initial condition and its forecast. We find an upper bound for the numerical model error introduced by finite difference schemes used to solve the linear advection equation and analyse its order of convergence.

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CP16

Structure Oriented Attributes Using Cuda Kernels for Oil Exploration

In this talk we present a class of structure oriented filters which are based on 3D gradient structure tensor approach. These kind of filters can be used to compute many orientation attributes encased in seismic data and its can help to the seismic interpretation. These filters allow to determinate local orientation, possible reflection terminations and smoothing of the data in the directions of the local orientation. The computation is done on a multi-GPU machine using CUDA. Computation and visualization on-the-fly (Real Time) can be done. In this case, we have used a 3D synthetic data to show results.

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CP16

Mpi Geometrical Partitioner

Data partitioning has a key importance in parallel computations. We present a new MPI geometrical partitioner which includes Recursive Coordinate Bisection, Recursive Internal Bisection and Hilbert Space Filling Curve algorithms based on fast parallel randomized selection algorithm. We compare our partitioner with state-of-the-art partitioner Zoltan on a data set arisen in real reservoir simulations and show that our algorithms generates partitioning of the same quality, but are considerable faster.

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CP16

Hypergraph Partitioner for Reservoir Simulations

Data partitioning is one of the most important procedures in parallel computations. We present a new hypergraph partitioning algorithm based on multilevel approach and intended for application in modern reservoir simulations. It includes new hypergraph coarsening schemes based on mixed vertex-hyperedge coarsening and can utilize geometrical information from underlying grids. Being compared with state-of-the-art partitioner Zoltan, our algorithm shows comparable quality, while considerable better performance as shown by examples arisen in real reservoir simulations.

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CP17

A High Order Accurate Solution Technique for Free Space Scattering Problems in Variable Media

This talk describes a new technique for solving free space scattering problems where there is localized variation from constant coefficient. In the region of variable media, an approximate Dirichlet-to-Neumann operator is constructed by a composite spectral method. This operator is then coupled to the rest of space via an integral equation that is amenable to fast solvers, has second kind behavior and is high order accurate. Numerical results illustrate the performance of the method.

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CP17

Pseudo-Spectral Method for Elliptic Interface Problems with Discontinuous Coefficients and Singular Sources

The aim of this talk is to solve elliptic interface problem with discontinuous coefficient and singular source term by spectral collocation method. First, we develop an algorithm for the elliptic interface problem defined in the simple domain with simple interface and then generalize it to curved interface. For complicated domain with curved interface we use spectral element collocation method. We give some numerical experiments to show efficiency of our algorithm and its spectral convergence.

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CP17

Delta Functions and the Euler-Maclaurin Formula

One aspect of the Chebfun software project is numerical computation involving delta functions. This relates to solutions of differential equations involving Green's functions and to the Euler-Maclaurin formula and related results quantifying the accuracy of the trapezoid rule applied to analytic functions — also to the theory of hyperfunctions. We present recent results in this area.

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CP17

Anti-Differential Operators: An Application of the Pseudo-Inverse

This talk presents approaches to approximate diagonalization of variable-coefficient differential operators using similarity transformations of operators rather than matrices. The similarity transformations are constructed using canonical transformations of symbols and anti-differential operators, which use the pseudo-inverse of the differentiation operator, for making lower-order corrections. Numerical results indicate that the symbols of transformed operators can be made to closely resemble those of constant-coefficient operators, and that approximate eigenfunctions can readily be obtained.

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CP17

Numerical Methods for the Poisson-Fermi Equation in Electrolytes

The Poisson-Fermi equation is applied to and numerically studied for electrolytes and biological ion channels in three dimensional space. This is a fourth-order nonlinear PDE that deals with both steric and correlation effects of all ions

and solvent molecules involved in a model system. Various numerical methods are developed to tackle a range of numerical problems concerning geometric singularities, the fourth-order term, nonlinearity, stability, efficiency, and effectiveness. The steric and correlation effects are demonstrated by showing good agreement with Monte Carlo simulation data for a charged wall model and an L type calcium channel model.

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CP17

A Overlapping Surface Decomposition Based Kernel-Free Boundary Integral Method for Variable Coefficient Elliptic Pde

An overlapping surface decomposition based kernel-free boundary integral method for variable coefficient elliptic partial differential equations will be presented in this talk. The method avoids direct computation of boundary integrals involving the Green's function and approximates the boundary integral with a structured grid based solution, which solves an equivalent interface problem on a larger regular box. The method works with complex domains defined implicitly through a level set function. The method does not need the generation of unstructured grids for both the problem domain and its boundary.

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CP18

Logconcavity of Compound Distributions with Applications in Stochastic Optimization

Compound distributions come up in many applications telecommunication, hydrology, insurance, etc.), where some of the typical problems are of optimization type. Logconcavity property is paramount in these respects to ensure convexity. We prove the logconcavity of some compound Poisson and other compound distributions by the use of Turan-type inequalities on some orthogonal polynomials.

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CP18

Optimal Preventive Maintenance and Repair Policies for Multi-State Systems

This paper studies the optimal preventive maintenance (PM) policies for multi-state systems. The scheduled PMs can be either imperfect or perfect type. The improved effective age is utilized to model the effect of an imperfect PM. The system is considered as in a failure state once its performance level falls below a given customer demand level. If the system fails before a scheduled PM, it is repaired and becomes operational again. We consider three types of major, minimal, and imperfect repair actions, respectively. The deterioration of the system is assumed to follow a non-homogeneous continuous time Markov process with finite state space. A recursive approach is proposed to efficiently compute the time-dependent distribution of the multi-state system. The main implication of our results is that in determining the optimal scheduled PM, choosing the right repair type will significantly improve the efficiency of the system maintenance.

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CP18

Developing Approximation Algorithms for Risk-Averse Stochastic Selection Problems

We consider a supplier facing a single period of uncertain demands and revenues in a collection of markets. The supplier chooses markets z and other decisions y to minimize a risk measure ρ of a cost function $\Gamma(y, z)$. This function includes lost revenues in deselected markets as well as logistics and newsvendor-type costs for the collection of selected markets. We develop high-probability constant-factor approximation algorithms to minimize $\rho(\Gamma(y, z))$ using rounding and sample average approximation.

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CP18

Geometric Asian Options under Heston Model: Pricing and Hedging

In this talk, we derive semi-analytic closed-form solution for price geometric Asian options when the underlying asset prices follow Heston's stochastic volatility model. Our method involves the generalized Fourier transform techniques. In addition, we derive the discrete-time variance optimal hedging strategy and the corresponding expected hedging error explicitly. Numerical results for prices and hedging strategies are presented with comparison of computational stability, efficiency and accuracy.

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CP18

Problem of Non-Monotone Quadratic Estimating Equations in Saddlepoint Approximating the Moving Average Model of Order One

Here our aim is to approximate the distribution of maximum likelihood estimator (MLE) of moving average model of order one [MA(1)] using the approach introduced by Daniels (1980) . Under this method, the MLE of the MA (1) parameter is expressed as a quadratic estimating equation (QEE). Monotone QEE whose unique root is the estimator of interest, the profiling out of nuisance parameters, and the accurate saddlepoint approximations to the cumulative distribution function of the MLE are some of the key steps of the method. When the QEE is not monotone with respect to the parameter, above approach cannot be followed. Therefore for the case of non-monotone QEE of the MLE, we try to apply a method that combines the results of both Skovgaards (1990) and Butlers (2007). According to the obtained results, it is clear that the above approach gives pretty good approximations though there are some slight disagreements when the value of the true parameter is close to one.

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CP19

Low-Reynolds-Number Swimming in Two-Phase Fluids

The fluid media surrounding many microorganisms are often mixtures of multiple materials with very different physical properties. The composition and rheology of the mixture may strongly affect the related locomotive behaviors. We study the classical Taylors swimming sheet problem within a two-fluid model, which consists of two intermixed fluids with different properties. Our results indicate that the swimming behavior may change substantially relative to those for a single-phase fluid.

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CP19

A Continuum Model for the Simultaneous Growth and Deformation of Biofilms

Microbial Fuel Cells are water treatment systems that use bacteria to break down wastewater nitrates while simultaneously generating electricity. A key factor in their efficiency is balancing the biofilms growth from nutrient consumption and erosion due to the surrounding fluid. We have coupled biofilm growth and deformation in a novel continuum model using Morphoelasticity Theory. The model tracks the evolving biofilm surface using the Level Set Method combined with the eXtended Finite Element Method (XFEM).

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CP19

Stable Explicit Interface Advancing Scheme for Fluid-Solid Interaction with Applications to Fish Swimming Simulation

We propose a numerical scheme for fluid-structure interaction when there are both elastic and rigid bodies inside the fluid. There can also be rigid bodies lying inside the elastic bodies. To develop a numerical scheme, we have to deal with the famous quadratic nonlinearities in the governing equations of the fluid and the rigid body. We use a natural semi-implicit discretization with *explicit* fluid-structure interface advancing. Consequently, the scheme does not require Newton type iterations. The scheme is characteristics-free even though we are working on a time varying domain for the fluid. All those features make the numerical scheme very efficient. We prove the unconditional stability of the *fully discrete scheme*. As an application, we perform the fish swimming simulation and numerically confirm some observations made by Purcell in 1976 concerning how microorganisms swim in a very viscous liquid.

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CP19

Eulerian/Lagrangian Sharp Interface Schemes for Compressible Multimaterials

We present multi-material simulations using both Eulerian and Lagrangian schemes. The methods employed are based on classical Godunov-like methods that are adapted to treat the case of interfaces separating different materials. In the models considered the gas, liquids or elastic materials are described by specific constitutive laws, but the governing equations are the same. Examples of gas-gas and gas-elastic material interactions in two space dimensions are presented.

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CP19

A Supercavitating Flexible Hydrofoil in a Stream of Ideal Fluid

We consider a cavitation problem for a flexible hydrofoil in a stream of ideal fluid with a Tulin single-spiral-vortex cavity closure condition. Several geometries of the hydrofoil are studied including a straight hydrofoil, a wedge, and a polygonal hydrofoil. The last case is used as an approximation to study a cavitating circular hydrofoil. The physical problem in all cases is reduced to a Riemann-Hilbert problem and then further reduced to a system of algebraic and transcendental equations. The later is solved numerically. The numerical results for certain geometries are presented.

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CP20

Extreme Events and Travel Time Reliability in Coupled Spatial Networks

Transport process on spatial networks can represent a lot of real world systems, which are often interdependent. This paper studies the extreme events (EE) on coupled spatial networks. The occurrence probability of EE on the coupling nodes depends strongly on the routing strategy and the density of commuters. As a result, the travel time reliability of the networks is also affected. To optimize the system, one needs to enhance the capacity of coupling nodes.

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CP20

Optimization of Two and Three-Link Snake-Like Locomotion

We analyze two- and three-link planar snake-like locomotion and optimize the motion for efficiency. The locomoting system consists of two or three identical inextensible links connected via hinge joints, and the angles between the links are actuated as prescribed periodic functions of time. Efficiency is defined as the ratio between distance traveled and the energy expended within one period, i.e. the inverse of the cost of locomotion. The optimal set of coefficients of friction to maximize efficiency consists of a large backward coefficient of friction and a small transverse coefficient of friction, compared to the forward coefficient of friction. For the two-link case with a symmetrical motion, efficiency is maximized when the internal angle amplitude is approximately $\pi/2$, for transverse coefficient sufficiently large. For the three-link case, the efficiency-maximizing paths are triangles in the parameter space of internal angles.

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CP20

Global Synchronization For Coupled Map Lattices in Ecology

We shall investigate non-smooth coupled map lattices in ecology. Such model is to describe how masting of a mature forest happens and synchronizes. The sufficient and necessary conditions for global synchronization of the model with lattice size 2 are to be presented.

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CP20

Stabilizing Gene Regulatory Networks Through Feed Forward Loops

The global dynamics of gene regulatory networks are known to show robustness to perturbations of different kinds: intrinsic and extrinsic noise, as well as mutations of individual genes. One molecular mechanism underlying this robustness has been identified as the action of so-called microRNAs that operate via different types of feedforward loops. We will present results of a computational study, using the modeling framework of generalized Boolean networks, that explores the role that such network motifs play in stabilizing global dynamics.

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CP20

Crosstalk Dynamics of Nls Solitons in Many-Body Interaction

We derive a general reduced model that describes the contribution of n-pulse interaction to the amplitude shift in fast collisions of N solitons of the NLS equation in the presence of generic weak nonlinear loss of the form $\sum_{m=0}^{m_c} \epsilon_{2m+1} |\psi|^{2m} \psi$, where ψ is the physical field. Our analytic calculations and numerical simulations show that n-pulse interaction with high n values plays a key role in fast soliton collisions in the presence of generic nonlinear loss. The scalings of n-pulse interaction effects with n and m and the strong dependence on initial soliton positions lead

to complex collision dynamics, which is very different from the one observed in fast soliton collisions in the presence of cubic loss [A. Peleg et al. Phys. Rev. A 82 053830 (2010)].

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CP20
A Unified Approach for Controlling Crosstalk in Broadband Optical Waveguide Systems

We present a unified approach for analyzing and controlling the dynamics of soliton amplitudes in broadband optical waveguide systems, induced by energy exchange (crosstalk) in pulse collisions. The approach, which is based on single-collision analysis along with collision rate calculations, shows that for a variety of waveguide systems, crosstalk-induced amplitude dynamics of N soliton sequences is described by N-dimensional Lotka-Volterra models. Stability analysis of the equilibrium states of the models uncovers ways for achieving stable transmission with equal nonzero amplitudes for all soliton sequences.

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CP20
Spiking Properties of Fractional Order Leaky Integrate-and-Fire Model

We develop the fractional order leaky integrate-and-fire model to study the fundamental properties of voltage dynamics on spiking activity. This dynamics depends on the voltage-memory trace that we define it as the integrated value of all past values of the voltage. The fractional order model displays slow spike frequency adaptation, spike latency and high interspike interval variability. Its spiking activity deviates from the Markov chain model, and reflects the temporal accumulated intrinsic membrane dynamics.

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CP21
Fractional Order Model of Rabies

Rabies is a preventable but still endemic disease in warm-blooded animals. We give a general one species-mathematical model to explain the transmission of rabies. This model consists of fractional order differential equations and it can be used to understand the dynamics of the disease in many different species.

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CP21
Analysis of Si Model for a Chronic Disease with Multiple Interacting Populations Using Subpopulations with Forcing Terms

As a system of differential equations describing an epidemiological system becomes large with multiple connections between subpopulations, the expressions for reproductive numbers and endemic equilibria become algebraically complicated which makes drawing conclusions based on biological parameters difficult. We present a new method which deconstructs the larger system into smaller subsystems, captures the bridges between the smaller systems as external forces, and bounds the reproductive numbers of the full system in terms of reproductive numbers of the smaller systems, which are algebraically tractable. This method also allows us to analyze the size and stability of the endemic equilibria. We demonstrate the model on the example of a sexually transmitted chronic disease with bisexual and heterosexual populations.

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CP21
Mathematical Modeling of the Spread of Antibiotic Resistant Bacteria in a Hospital

The increase in antibiotic resistance continues to pose a major public health risk leading to a more intense focus on ways to limit and even reduce this threat. In order for mathematical models to be useful in evaluating the potential effects of different treatment protocols or stewardship practices, the models must be refined to more accurately represent a typical hospital. In this talk, we focus on these refinements using both deterministic and stochastic modeling.

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CP21

Optimal Control of Influenza Model

This study considers an optimal intervention strategy for influenza outbreaks. Variations in the SEIAR model are considered to include seasonal forcing and age structure, and control strategies include vaccination, antiviral treatment, and social distancing such as school closures. We formulate an optimal control problem by minimizing the incidence of influenza outbreaks while considering intervention costs. We examine the effects of delays in vaccine production, seasonal forcing, and age-dependent transmission rates on the optimal control and suggest some optimal strategies through numerical simulations.

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CP21

Hybrid On-Off Control for An HIV Model Based on a Linear Control Problem

We consider a model of HIV infection with various compartments, including target cells, infected cells, viral loads and immune effector cells, to describe HIV type 1 infection. We show that the proposed model has one uninfected steady state and several infected steady states and investigate their local stability by using a Jacobian matrix method. We obtain equations for adjoint variables and characterize an optimal control by applying Pontryagins Maximum Principle in a linear control problem. In addition, we apply techniques and ideas from linear optimal control theory in conjunction with a direct search approach to derive optimal on-off HIV therapy strategies. The results of numerical simulations indicate that hybrid on-off therapy protocols can move the model system to a healthy steady state in which the immune response is dominant in controlling HIV after the discontinuation of the therapy.

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CP21

Spread of Avian Influenza Pandemic to Usa Via Air Travel

We introduce a two-patch mathematical model to forecast the global spread of pandemic avian influenza. We suppose that the pandemic starts in Asia and spreads to USA by air travel. We consider total of 12 major airports in Asia and USA. We derive the reproduction number of the two-patch model and compute the sensitivity of the parameters such as transmission and death rate of pandemic avian influenza.

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CP21

Utilizing Female-Killing Strategies in the Optimal Control of the Dengue Vector, *Aedes Aegypti*

Dengue fever is spread primarily by *Aedes aegypti* mosquitoes. Although traditional control measures have been implemented for many years, dengue remains endemic in many parts of the world. Recently, control strategies involving the release of genetically modified mosquitoes have been proposed. Among those for *Ae. aegypti* that have seen the most progress are Female-Killing (FK) strategies. Cage experiments showed that repeated introductions of individuals from one FK strain of *Ae. aegypti* led to either reduction or extinction of caged wild-type populations. Any future open releases should be conducted according to plans that consider temporal and financial constraints. We develop an optimal control model to assess the role that such constraints will play in conducting FK releases. Through numerical simulation, we obtain optimal release strategies for a variety of scenarios and assess the feasibility of integrating FK releases with other forms of vector control.

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CP22

A Perfect Match Condition for Point-Set Matching Problems Using the Optimal Mass Transport Approach

We study the performance of optimal mass transport-based methods applied to point-set matching problems. The present study, which is based on the L2 mass transport cost, states that perfect matches always occur when the product of the point-set cardinality and the norm of the curl of the non-rigid deformation field does not exceed some constant. This analytic result is justified by a numerical study of matching two sets of pulmonary vascular tree branch points whose displacement is caused by the lung volume changes in the same human subject. The nearly perfect match performance verifies the effectiveness of this mass transport-based approach.

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CP22

Dynamic Congestion and Tolls with Mobile Source Emission

This paper proposes a dynamic congestion pricing model that takes into account mobile source emissions. We consider a tollable vehicular network where the users selfishly minimize their own travel costs including travel time, early/late arrival penalties and tolls. On top of that, we assume that part of the network can be tolled by a central authority whose objective is to minimize both total travel costs of users and total emission on a network-wide level. The model is formulated as a mathematical programming with equilibrium constraints (MPEC) problem and then reformulated as mathematical programming with complementarity constraints (MPCC). The MPCC is solved using a quadratic penalty-based gradient projection algorithm.

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CP23

Stokes Flow Past a Porous Body of Arbitrary Shape

Flow past a permeable body of an arbitrary shape in an incompressible fluid at low Reynolds number is discussed. The Brinkman equations are assumed in the permeable body and an approximate, analytic solution is obtained for an arbitrary flow. The results are compared with the exact solution when the body is spherical. The effect of permeability on the physical parameters of the flow is discussed.

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CP23

Slip Flow Past Bodies of Arbitrary Shape in a Viscous, Incompressible Flow

Stokes flow past a body of arbitrary shape satisfying slip-stick boundary conditions is discussed and an analytic but approximate solution is obtained in the entire domain. The method is illustrated in the case of a singularity driven flow due to a Stokeslet outside an ellipsoid. The effect of the slip-parameter on physical quantities like drag as well as the convergence of the method for different values of the slip-parameter are discussed.

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CP23

Computing Nonlinear Waves of the Korteweg-De Vries and Korteweg-De Vries-Burgers Equations in Invariant Structures

Periodic and aperiodic travelling waves of the Korteweg-de Vries and Korteweg-de Vries-Burgers equations are reduced to canonical dynamic equations for pulsations and oscillations of conservative and dissipative systems in a cubic potential well. By integrated computing, the canonical dynamic equations for the conservative and dissipative systems are resolved in invariant trigonometric and exponential-trigonometric structures, respectively. Comparisons of symbolic-numeric solutions with those computed by the Fehlberg fourth-fifth order Runge-Kutta method and the Taylor series are provided.

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CP23

A Massively Parallel Finite Element Solver for High Definition Chromatography Simulations

Packed bed chromatography is a very important unit operation, applied by biotechnology industry for purifying target molecules from contaminants. Aiming at high definition chromatography simulations, we present a finite element approach which accurately captures all relevant transport and binding phenomena in miniaturized chromatography devices. We apply a stabilized space-time FEM to solve both low Reynolds number fluid flow and convection-dominated transport and binding of solute molecules. Our code runs efficiently on several thousand compute cores.

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CP23

Two-Way Coupling of Lagrangian and Eulerian Governing Equations for Particles in Incompressible Fluids

Spectral methods formulations of Navier-Stokes equations for an incompressible fluid and the small particle equation of motion are coupled together in a numerical scheme for investigating interactions between the fluid and the dispersed particles in the fluid. In this two-way coupling numerical scheme, the fluid velocity field affects the motion of the particles while the surface forces generated by the particles affecting the fluid. The solver utilizes FFT to handle Fourier expansions in two directions and Chebychev polynomial expansion in the third. In order to handle instabilities of the fluid motion, as a semi-implicit time stepping scheme, Modified Adams-Bashforth/Crank-Nicolson is used. The method is demonstrated on two problems: (i) rise of bubbles in water columns; (ii) motion of particles in Benard cells.

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CP23

Effectiveness of Stiffly-Stable Projection Schemes for Smooth Particle Hydrodynamics Simulations of Transient Viscous Flows

Smoothed particle hydrodynamics is a meshless collocation method that provides a natural platform for solving the Navier-Stokes equations in a Lagrangian framework. While the method remains an attractive choice for simu-

lating viscous flows, the standard numerical scheme incurs a severe timestep restriction due to the use of an artificial compressibility assumption and explicit timestepping. In this work we implement a stiffly-stable projection scheme and demonstrate its ability to efficiently achieve more accurate results for transient flows at low Reynolds number.

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CP24

A Discrete Model of Denitrification in Pseudomonas Aeruginosa

Pseudomonas aeruginosa is a metabolically flexible member of the Gammaproteobacteria. Under anaerobic conditions and the presence of nitrate, Pseudomonas aeruginosa can perform (complete) denitrification, a respiratory process of dissimilatory nitrate reduction to nitrogen gas via nitrite, nitric oxide and nitrous oxide. To our knowledge, our model is the first mathematical model of denitrification for this bacterium. This study aims to capture the effect of phosphate on a denitrification network of Pseudomonas aeruginosa in order to shed light on the reason of greenhouse gas nitrous oxide accumulation during oxygen depletion in Lake Erie.

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CP24

Models for Comparing Chikungunya and Dengue

Chikungunya is a re-emerging mosquito-borne infectious disease that is spreading rapidly across Africa and Asia. Two common mosquito species, *Aedes aegypti* and *Aedes albopictus*, are competent vectors for chikungunya virus. We design and analyze an ordinary differential equation model with mosquito dynamics for the spread of both chikungunya and dengue. The model is parameterized using current literature, data, and lab experiments. We show that dengue and chikungunya exhibit different disease dynamics, resulting in different risk profiles and providing areas of focus for greatest effect in controlling the spread of chikungunya.

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CP24

Modeling Sustainability of Biological Systems

The possibility of interacting with biological systems enables us to design adequate strategies for their use and preservation ranging from ecosystems to synthetic biological constructions. In this talk we first provide an overview of the possible applications of control theory to the design of sustainable policies at several space-time scales and then we focus on specific aspects of the corresponding mathematical modeling. We present a more technical example related to synthetic biology.

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CP24

Modeling the Cell Biology of the Heat Shock Response of Barley Aleurone Cells

When heat shocked, plant cells distribute their energy to make a very different set of proteins than when at normal temperatures. When barley is heat shocked, the cells' production of α-amylase and other secretory proteins is largely reduced and a set of heat shock proteins that repair damaged proteins is produced. The purpose of this project is to create and test a mathematical model to analyze what elements have influenced α-amylase production. Our current model and simulations are able to capture the impact of different temperature regimes and levels of fluidity on α-amylase synthesis and are in good qualitative agreement with the experimental data.

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CP25

Numerical Validation of Data Assimilation Codes Generated by the Yao Software

The YAO software is a general framework used to generate codes that implement a numerical model. Furthermore YAO provides a toolbox to conduct assimilation data experiments. The CADNA library estimates numerical accuracy of a computation. It was integrated to YAO in order to provide automatically a numerical validation of complete assimilation processes. Several applications regarding oceanic and hydrographic modeling were generated using YAO-CADNA and were numerically validated.

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CP25

Uncertainty Quantification Based on Joint Response-Excitation Pdf Equations

We study the evolution equation of joint excitation-response PDF (REPDF) which generalizes the existing PDF equations and enables us to compute the PDF for any stochastic dynamical system and first order PDEs driven by colored noise. An efficient numerical method is developed for the evolution equation by using the adaptive discontinuous Galerkin (DG) method for the response space and probabilistic collocation method (PCM) combined with sparse grid for the excitation space. The effectiveness of the proposed new algorithm is demonstrated in two prototype applications dealing with randomly forced nonlinear oscillators and the results are compared with kernel density estimation based on Monte Carlo simulation and the solution to the effective Fokker-Planck equation. Also, stochastic inviscid Burgers equation is studied to investigate the PDF when discontinuity occurs in the physical domain.

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CP25

Separating Intrinsic and Parametric Uncertainty in Stochastic Simulations

We present a method of UQ for stochastic simulations. For these types of simulations random events cause quantities of interest (QOI) to vary over a wide range of values for fixed input parameters. Further uncertainty is introduced from imprecisely known parameters. We discuss a novel statistical surrogate model that combines multiple emulation strategies to represent intrinsic and parametric variation separately. QOI samples from the simulation and from the statistical surrogate model are combined to describe the uncertainty in the model's prediction.

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CP25

***mystic*: a Framework for Uncertainty Quantification and Predictive Science**

We have built a robust software framework (*mystic*) that lowers the barrier to solving high-dimensional and highly-constrained global optimization problems. *mystic* provides tools for rigorously constraining design space, including suites of standard and statistical constraints, discrete and symbolic math, and uncertainty quantification. *mystic* is built to leverage high-performance parallel computing, and has been used in calculations of materials failure under hypervelocity impact, elasto-plastic failure in structures under seismic ground acceleration, and risk in financial portfolios.

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CP25

Multi-Scale Modeling with Generalized Dynamic Discrepancy

Bayesian calibration can be an effective tool for multi-scale modeling, since it enables a quantification of uncertainty created through scale-bridging through the application of either experimental or high-fidelity simulator data. In order to realize this promise in dynamic systems, small-scale models – such as those governing transient chemical kinetics – require dynamic approaches to model discrepancy. But a traditional approach to discrepancy must incorporate dependence on a functional input space in order to capture the dynamic character of a model, which is often impractical. A new approach to dynamic discrepancy is introduced. Strictly speaking, the approach is intrusive, but is broadly applicable to a number of dynamic problems. The dynamic discrepancy approach reduces the dependency of the discrepancy function to a concurrent scalar value of time-dependent inputs. Stochastic differential equations engendered by the approach are solved through the use of the Bayesian Smoothing Spline Analysis of Variance (BSS-ANOVA) formalism. This approach to discrepancy leads to portability, and to an attendant iterative approach to scale-bridging. The methods are demonstrated in the context of problems in chemical process modeling.

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MS1

Title Not Available at Time of Publication

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MS1

Fast Direct Solvers for Integral Equations

The last several years have seen great progress in the development of linear complexity direct solvers for the large sparse linear systems arising upon finite element and finite difference discretizations of elliptic PDEs such as the Laplace and Helmholtz equations. This talk will describe recent work on direct solvers for the dense linear systems associated with integral equation formulations. Recently, linear complexity algorithms with high practical efficiency have been developed for variable coefficient problems in the plane. We will describe these techniques, and will show tentative results for how they can be extended to handle boundary integral equations in 3D.

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MS1

Randomized Sparse Direct Solvers with Applications

We present some fast randomized structured direct solvers for large sparse linear systems, including the matrix-free variations. The work involves new flexible randomized methods for exploiting structures in large matrix computations, so as to provide both higher efficiency and better applicability than some existing structured methods. New efficient ways are proposed to conveniently perform various complex operations which are difficult in standard rank-structured solvers. Nearly O(n) complexity for various situations will be shown. Extension of the techniques to least squares, eigenvalue problems, and sparse selected inversion will also be given. We also study the following issues: 1. Develop matrix-free structured solvers and update a structured factorization when few matrix entries change. 2. Relaxed rank requirements in structured solvers, especially for 3D problems. 3. Develop structured preconditioners for problems without significant rank structures, and analyze the effectiveness.

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MS1

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MS2

Coursework and Programs in Applied and Computational Mathematics at the University Level

Abstract not available at time of publication.

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MS2

Examples of Good Practice in Mathematical Modeling Education

Abstract not available at time of publication.

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MS2

Coursework in Applied and Computational Mathematics at the High School Level

Last Fall, the working group discussions on possible 'Intro to STEM' coursework at the high school level were wide-ranging, thoughtful, and provocative. This portion of the mini-symposium will provide an overview of our critical questions, discuss data likely needed to address the questions, make recommendations for next tasks (including research topics), and explore links with both college readiness and undergraduate curriculum issues. Even within our small working group, many different viewpoints were expressed about the presence, success, and appropriate role of applied and computational mathematical sciences within the K-12 educational framework. Please join us to explore these ideas further in a constructive conversation.

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MS2

SIAM-NSF Workshop on Modeling Across the Curriculum: Introduction

In this talk, an introduction to the SIAM-NSF Workshop on Modeling across the Curriculum (August, 2012) will be presented. The meeting proposal pre-dated but responded to teh PCAST "Engage to Excel" report and its call for one million new college STEM graduates in the next decade. This talk will provide an overview of the workshop and some of the more recent developments.

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MS3

An Efficient Algorithm for Simulating the Evolu-

tion of Multiple Elastically Stressed Precipitates

In this talk, we present a space-time rescaling scheme for computing the long time evolution of multiple precipitates in an elastically stressed medium. The scheme is motived by a recent paper (Li, Lowengrub and Leo, J. Comput. Phys., 335 (2007), 554) for a single particle case. The algorithm is second order accurate in time, spectrally accurate in space and enables one to simulate the long time evolution of precipitates. The method relies on a space-time rescaling scheme to expedite the numerical simulation, and also employs a parallel adaptive treecode to speed up the GMRES solver. We will present numerical results.

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MS3

Mathematical Modelling and Numerical Simulations of Actin Dynamics in the Eukaryotic Cell

The aim of this talk is to present recent results on the study of cell deformation and cell movement by considering both the mechanical and biochemical properties of the cortical network of actin filaments and its concentration. Actin is a polymer that can exist either in filamentous form (F-actin) or in monometric form (G-actin) and the filamentous form is arranged in a paired helix of two protofilaments. By assuming that cell deformations are a result of the cortical actin dynamics in the cell cytoskeleton, we consider a continuum mathematical model that couples the mechanics of the network of actin filaments with its bio-chemical dynamics. Numerical treatment of the model is carried out using the moving grid finite element method. Furthermore, by assuming slow deformations of the cell, we use linear stability theory to validate the numerical simulation results close to bifurcation points. Far from bifurcation points, we show that the mathematical model is able to describe the complex cell deformations typically observed in experimental results. Our numerical results illustrate cell expansion, cell contraction, cell translation and cell relocation as well as cell protrusions. In all these results, the contractile tonicity formed by the association of actin filaments to the myosin II motor proteins is identified as a key bifurcation parameter.

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MS3

Modelling Cell Motility with the Evolving Surface Finite Element Method

We propose a framework for the modelling and simulation of cell motility. The membrane dynamics is governed by a geometric evolution law. For cell polarisation we postulate a reaction-diffusion system for species on the membrane. Protrusion is achieved by back-coupling these surface quantities to the geometric equation. The numerical method is based on surface finite elements for both the geometric and the surface equations. We include simulations of pseudopod-driven chemotaxis and the motion of keratocytes.

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MS4

Adaptive Least-Squares Methods for Viscoelastic Flows

This talk concerns solutions of viscoelastic flow problems by adaptive least-squares finite element methods. Model problems considered are the flow past a planar channel and a 4- to-1 contraction problems. In this talk, algorithms will be proposed to construct optimal adaptive mesh redistribution to resolve the high gradient region, the corner singularities and formation of vortices in the model problems. Numerical results of both Newtonian (Stokes) and Oldroyd-B model equations are presented.

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MS4

Can a Defect Correction Method Be Viewed As a Turbulence Model?

A method for resolving turbulent flows is sought, which is faster than the existing approaches, and competitive in terms of stability and accuracy. We introduce a Defect Correction Method (DCM) for approximating the averaged solution of (turbulent) Navier-Stokes equations, and we compare it against the Approximate Deconvolution Model of turbulence. We prove stability of the method, verify its accuracy numerically, and demonstrate the superiority of DCM in terms of CPU time.

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MS4

Least Squares Approach for Optimization Based Domain Decomposition

We consider solution algorithms for multi-physics problems, where a coupled system is formulated as an optimal control problem for domain decomposition. A Neumann type control is introduced to enforce a boundary condition on the interface of subdomains, and the control problem is reformulated as a least squares problem for which the Gauss-Newton algorithm is considered. Two examples will be presented for the approach; the Stokes-Darcy problem and a fluid structure interaction problem. Numerical results are presented to validate convergence and accuracy of the method.

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MS4

On Robust Discretizations for Coupled Flow Problems

Robust discretization of coupled flow problems like Rayleigh-Benard convection or the Nernst-Planck-Poisson-Stokes system in micro fluidics remains to be a challenging problem. Due to the multi-physics character of such flow processes, discretizations for the full nonlinearly coupled system have to respect many different qualitative properties of the underlying physical processes at the same time, e.g., discrete maximum principles for temperature or species concentrations and discrete mass conservation. This talk will focus on the problem of poor mass conservation in coupled flow problems. Poor mass conservation arises due to the impact of large irrotational forcings (in the sense of Helmholtz-Hodge decomposition) in the momentum equations, and reflects a lack of L^2-orthogonality of (only) discretely divergence-free and irrotational vector fields.

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MS5

Recent Development of the Nonlinear QR Algorithm for Genuine Nonlinear Eigenvalue Problems

In this talk, we first present the algorithmic improvements of the nonlinear QR algorithm of Kublanovskaya for solving genuine nonlinear eigenvalue problems. We show how to avoid the full rank-revealing QR decomposition to reduce computation and communication costs in the inner QR loop, and how to accelerate the rate of the convergence in the presence of multiple eigenvalues. In addition, we will discuss a number of numerical treatments in the implementation of the nonlinear QR algorithm towards a blackbox solver for small to medium size genuine nonlinear eigenvalue problems.

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MS5

Nonsymmetric Multigrid Preconditioning for Conjugate Gradient Methods

We numerically analyze the possibility of turning off post-smoothing (relaxation) in geometric multigrid when used as a preconditioner in conjugate gradient linear and eigenvalue solvers for the 3D Laplacian. The geometric Semi-coarsening Multigrid (SMG) method is provided by the hypre parallel software package. We solve linear systems using two variants (standard and flexible) of the preconditioned conjugate gradient (PCG) and preconditioned steepest descent (PSD) methods. The eigenvalue problems are solved using the locally optimal block preconditioned conjugate gradient (LOBPCG) method available in hypre through BLOPEX software. We observe that turning off the post-smoothing in SMG dramatically slows down the standard PCG-SMG. For the flexible PCG and LOBPCG, our numerical results show that post-smoothing can be avoided, resulting in overall acceleration, due to the high costs of smoothing and relatively insignificant decrease in convergence speed. We numerically demonstrate for linear systems that PSD-SMG converges nearly identical to flexible PCG-SMG if SMG post-smoothing is off. A theoretical justification is provided. [http://arxiv.org/abs/1212.6680]

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MS5

Structured Backward Relative Error Bounds for Eigenvalues of Tridiagonal Matrices

The variability of the sensitivity of eigenvalues of tridiagonals is illustrated in pictures. A few relative condition numbers that respect the sparsity structure are developed and put to use. Finally a way is shown to compute, in O(n) operations, a tight bound on the smallest maximal relative change to any parameter that makes a computed eigentriple exact. This is the most desirable accuracy measure that is warranted by the problem and complements the appropriate condition number.

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MS5

Bounds for the Rayleigh Quotient and the Spectrum of Self-Adjoint Operators

If x is an eigenvector of a self-adjoint bounded operator A in a Hilbert space, then the Rayleigh quotient (RQ) of the vector x, denoted by $\rho(x)$, is an exact eigenvalue of A. There are three traditional kinds of bounds for eigenvalue errors: a priori bounds via the angle between vectors; a posteriori bounds via the norm of the vetor residual; mixed type bounds using both the angle and the norm of the residual. We propose a unifying approach to prove known bounds of the spectrum, analyze their sharpness, and derive new sharper bounds. The proof approach is based on novel RQ vector perturbation identities.

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MS6

Finite Element Approximation of Steady Flows of Incompressible Fluids with Implicit Power-Law-Like Rheology

We present the analysis of finite element approximations of implicit power-law-like models for viscous incompressible fluids. In contrast to the recent existence proof in [1], a practical convergent finite element method needs to perform the different limits simultaneously. This introduces several serious difficulties:

- For common stable finite element pairs the velocity approximations are typically not exactly divergence free.
- We require a finite element counterpart of the Acerbi-Fusco Lipschitz truncation of Sobolev functions.

[1] M. Bulíček, P. Gwiazda, J. Málek, and A. Świerczewska-Gwiazda, On steady flows of incompressible fluids with implicit power-law-like rheology, Adv. Calc. Var. 2 (2009), no. 2, 109–136.

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MS6

On Unsteady Flows of Implicitly Constituted Incompressible Fluids Subject to Implicitly Constituted Boundary Conditions

We study flows of incompressible fluids in which the deviatoric part of the Cauchy stress and the symmetric part of the velocity gradient are related through an implicit equation. Although we restrict ourselves to responses characterized by a maximal monotone graph, the structure is rich enough to include power-law type fluids, stress power-law fluids, Bingham and Herschel-Bulkley fluids, etc. We are interested in the development of (large-data) existence theory for internal flows of such fluids subject to various type of boundary conditions. We show, in particular, that the implicit relations on the boundary can have a significant impact on the development of the mathematical theory even for the Navier-Stokes equations and its generalization.

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MS6

On Spatial Distribution of the Discretization and Algebraic Error in Numerical Solution of Partial Differential Equations

In the adaptive numerical solution of partial differential equations, local mesh refinement is used together with a posteriori error analysis in order to equllibrate the discretization error disctribution over the domain. Since the discretized algebraic problems are *not solve exactly*, a natural question is whether the disctribution of the algebraic error is analogous to the distribution of the discretization error. We demonstrate that this may not hold. On the contrary, the algebraic error can significantly dominate the total error in some part of the domain.

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MS6

Fluids and Solids Described by Implicit Constitutive Theories

In this talk I will discuss implicit constitutive theories to describe the response of fluids and solids. Such models seem most appropriate for describing fluids whose material moduli depend on the pressure and shear rate. Implicit theories for elastic solids include as special subclasses Cauchy and Green elastic solids and thus provide a much larger class of models within which one can describe the elastic response of solids. Moreover, the linearization of such models leads to models that are well suited to describe the fracturing of elastic solids.

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MS9

Some Lessons I Learned

Abstract not available at time of publication.

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MS9

Adventures at Convergence of the Mathematical and Biological Sciences

Onwards and upwards. In this talk, I will discuss my meandering career path. This will include a discussion of finding the right graduate program on the second try and finding an academic with the right balance in a tough job market. Throughout the journey, experiences and challenges will be highlighted.

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MS9

Experiences As a Program Officer

Abstract not available at time of publication.

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MS10

On a New Stable Basis for Rbf Interpolation

It is well-known that RBF interpolants suffer of bad conditioning if the basis of translates is used. The new basis arises from a weighted singular value decomposition of the kernel matrix. The basis is related to a discretization of the compact operator $T_\Phi :\to$,

$$T_\Phi[f](x) = \int_\Omega \Phi(x,y) f(y) dy \quad \forall x \in \Omega$$

and provides a connection with the continuous basis arising from an eigen-decomposition of T_Φ. Using the eigenvalues of T_Φ, we provide convergence estimates and stability bounds for interpolation and discrete least-squares approximation.

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MS10

The Hilbert-Schmidt SVD: An Alternative Interpretation for the RBF-QR Method

The RBF-QR method was introduced in [Fornberg & Piret, A stable algorithm for flat radial basis functions on a sphere, SIAM J. Sci. Comp. 30 (2007), 60–80] as a way to deal with the ill-conditioning that is often associated with radial basis function methods. Since then, the method has been adapted to more general settings by several other authors. In particular, in [Fasshauer & McCourt, Stable evaluation of Gaussian RBF interpolants, SIAM J. Sci. Comput. 34 (2012), A737–A762] the method was formulated within the context of eigenfunction expansions of the (positive definite) kernels of associated Hilbert-Schmidt operators. In this talk we will introduce a matrix factorization of the from $\mathsf{K} = \Psi\Lambda\Phi^\mathsf{T}$ of the RBF interpolation matrix K in terms of matrices generated by the orthogonal eigenfunctions. This *Hilbert-Schmidt SVD* is not a traditional singular value decomposition of K, but shares a number of properties with the SVD. Most importantly, the matrix factors are obtained without ever having to form the ill-conditioned matrix K. We will use the Hilbert-Schmidt SVD to present a particularly simple implementation of the RBF-QR method, and also to obtain MLE and GCV estimates of the "optimal" RBF shape parameter within the RBF-QR framework. This is joint work with Mike McCourt.

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MS10

High-order Vector Decomposition with Radial Basis Functions

The Helmholtz-Hodge decomposition guarantees the natural decomposition of any smooth vector field into certain divergence-free, curl-free and harmonic components. This decomposition is fundamental to the analysis of vector fields, especially those arising in electromagnetic or computational fluid dynamics. We describe a meshless kernel method, based on radial basis functions, that leads to a high-order approximation of the decomposition on a large class of bounded domains. Error estimates will be presented, and some numerical examples will be given.

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MS10

A Comparison Between the RBF-Finite Difference and the RBF-Partition of Unity Methods for Shallow Water Flows on the Sphere

The shallow water wave equations are an idealized test-bed for the horizontal dynamics (known as the dynamical core) of all 3D climate model developments. We present two meshfree, high-order, computationally efficient methods for these equations that are both based on radial basis functions (RBFs). The first is the relatively new RBF-finite difference method and the second is the new RBF-partition of unity method. We compare both methods in terms of accuracy, efficiency, and scalability for several well-known test cases.

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MS11

Mimetic Curvilinear Environmental Model: Harnessing the Power of Gpu's

Castillo-Grone Mimetic (CGM) difference operators have shown to perform superior in many fields that deals with numerical solution of partial differential equations (PDEs). Majority of the problems in environmental sciences, including large scale fluid flow in the oceans and Atmosphere, can be expressed by PDEs using divergence and gradient operator. In this talk a new numerical model, capable of simulating geophysical fluid, based on CGM difference operators is introduced. Furthermore, this model harnesses the power of the many cores available on the Graphics Processing Units (GPUs). Hence, the model implementation on the GPUs is discussed and some performance analysis is provided.

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MS11

Data Assimilation for Hydrodynamical Modeling of San Quintin Bay, Ensenada, B.C., Mexico

San Quintin Bay (SQB), B.C. forms an interesting ecosystem in which aquaculture has been developed for more than 30 years. The most important biological process for cultivating organisms is the reproductive cycle which is principally regulated by the amount and quality of the food as well as by temperature and salinity. Furthermore, the hydrodynamic state has to be known with high accuracy for efficient ecological monitoring of the bay. A regional numerical model using Delft3d is presented to provide information on the water velocities and water elevation around SQB. In this study data assimilation aims to incorporate measured observation into a dynamical system model in order to produce accurate estimates of all the current state variables of the system. To pursue this goal, the open-source software environment OpenDA for sensitivity analysis and simultaneous parameter optimization is used. The purpose of this study is to give short-term operational predictions of the hydrodynamical state of the SQB. A limited set of coastal measurement observed data can be used to explore how filtering methods can be used to combine model output with observed data.

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MS11

Stochastic Differential Equation Modeling of Precipitation in Convection

Recent studies have used statistical measures inferred from observational data to characterize the transition to deep convection at a critical value of column water vapor (CWV), around which there is a sharp transition in mean precipitation and a peak in precipitation variance. However, the parameters used in these variable functions are derived from a combination of empirical and theoretical estimates. In this study, the functional relationships between the precipitation, column water vapor and the transition probability to strong convection are estimated, and simulation statistics are analyzed with respect to observations to estimate the parameters in the stochastic model. This parameterization includes three stochastic components: a stochastic trigger that turns the precipitation state on and off (a Markov jump process), and stochastic closures which represent variability in precipitation and moisture convergence/divergence.

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MS11

Application of a Shallow Water Hydrodynamics Model to Study Circulation Patterns in Lake Valencia, Venezuela

A numerical model for simulation of shallow water flows in any water body is presented. It uses a MacCormack-TVD numerical scheme to solve simultaneously the continuity and momentum equations in the Saint Venants system of equations. The model allows calculation of tides and currents generated by wind and it was applied to Lake Valencia, Venezuela. A set of wind-driven circulations patterns were generated from field data. Although the use of shallow water models is fairly standard in the study of lakes circulation, its application to the Lake Valencia is new. Therefore, the steady circulation patterns developed in this numerical study represent an original contribution.

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MS12

Numerical Optimization of Laplacian Eigenvalues of 4D Domains

In this talk we consider the numerical solution of shape optimization problems involving Laplacian eigenvalues of 4D domains. The eigenvalue problems are solved by the Method of Fundamental Solutions with a particular choice for the location of the source points.

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MS12

Minimal Convex Combinations of Sequential Laplace-Dirichlet Eigenvalues

In this talk, the shape optimization problem where the objective function is a convex combination of three sequential Laplace-Dirichlet eigenvalues is presented. Our computations based on the level set approach and the gradient decent method not only reproduce previous results on signal eigenvalue optimization but also extend these results to sequential eigenvalue problems. Several properties of minimizers are studied computationally, including uniqueness, connectivity, symmetry, and eigenvalue multiplicity.

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MS12

Spectral Shape Analysis with Applications in Medical Imaging

Complex geometric objects have gained much importance in many applied fields. Methods to compare and analyze shape are essential to process the vast amounts of available geometric data. This talk will give an overview on spectral methods in shape analysis. Eigenvalues and eigenfunctions of the Laplace-Beltrami operator yield powerful tools to describe and analyze shape. Due to their isometry invariance they are optimally suited to deal with non-rigid shapes often encountered in nature, such as a body in different postures. The normed beginning sequence of the spectrum ('ShapeDNA') can be used as a global signature for shape matching, while the eigenfunctions and their topological analysis can be applied for shape registration, segmentation and local shape analysis. Examples of applications such as database retrieval of near isometric shapes, statistical shape analysis of subcortical structures of the human brain and hierarchical segmentation of articulated shapes will be presented.

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MS12

A Natural Extension of Laplacian Eigenfunctions from Interior to Exterior and its Application

In 2008, we proposed a method to compute eigenfunctions of Laplacian defined on a domain of general shape (satisfying some nonlocal boundary condition) by diagonalizing an integral operator commuting with the Laplacian. These eigenfunctions can be harmonically extended to the exterior of the original domain by the Nyström extension. In this talk, we discuss their properties, the relationship with the so-called Krein–von Neumann self-adjoint extension of unbounded symmetric operators, and certain applications including image extrapolation.

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MS13

On Integral Kernels with Applications to Shape Problems

A shape representation is proposed based on the integral kernels and a variational framework is presented for the construction of diffeomorphisms that establish meaningful correspondences between images, in that they preserve the local geometry of singularities such as region boundaries. At the same time, the shape representation allows enforcing shape information locally in determining such region boundaries. Our representation is based on a kernel descriptor that characterises local shape. This shape descriptor is robust to noise and forms a scale-space in which an appropriate scale can be chosen depending on the size of features of interest in the scene. In order to preserve local shape during the matching procedure, we introduce a novel constraint to traditional approaches to estimate diffeomorphic deformations, and enforce it in a variational framework.

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MS13

Schrdinger Distance Transforms, Gradient Density Estimation and Application to Vision Problems

Methods based on Hamilton-Jacobi and classical mechanics formulations have proliferated over the past thirty years. In contrast, methods based on Schrdinger and quantum mechanics formulations are hard to find. We redress this imbalance by developing a Schrdinger distance transform (SDT) based on solutions to a linear differential equation. Next, we show that the squared magnitude of the Fourier transform of the SDT, when appropriately normalized, is an approximation to the distance transform gradient density function.

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MS13

The Implicit Closest Point Method for the Numerical Solution of Partial Differential Equations on Surfaces

Many applications in the natural and applied sciences require the solutions of partial differential equations (PDEs) on surfaces or more general manifolds. The Closest Point Method is a simple and accurate embedding method for numerically approximating PDEs on rather general smooth surfaces. In this talk, we describe the implicit Closest Point Method for surface PDEs. Key features of the method are that it maintains the order of accuracy of the discretization of the underlying embedding PDE, it works on sharply defined bands without degrading the accuracy of the method, and it applies to general smooth surfaces. We demonstrate the method on a variety of problems including the Laplace-Beltrami eigenvalue eigenvector problem, and problems involving up to fourth order derivatives. This talk describes joint work with Colin Macdonald and Jeremy Brandman.

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MS13

Fluctuating Distance Fields with Connections to Modica-Mortola, Eigenspaces of Positive Definite Operators and Discrete Algorithms

Adding a non-local term, namely squared expectation, to the Modica-Mortola length functional gives rise to a surprising result: A diffuse field which is distance, curvature and part aware arises. In the discrete setting, this field is the projection of a shape indicator function to the eigen-space of a rank one modification to the Laplace operator. Among its several properties, the field suggests an interesting skeleton model in the form: gross structure + deformable parts + residual. In this set up, distinction between shape skeleton and the shape segmentation fades away. The talk focuses on discrete problems.

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MS14

Models and Products, Processes, and Measurements

Inventions often involve the application of an idea from one area to solve a problem in another. Applied math fits this paradigm in a number of ways. We will review some concrete examples from history and current experience showing successful implementation. One limitation in the past was the limit of practical computation; some mathematical models or algorithms which once were impractical are now validated, vindicated, and a part of everyday life.

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MS14

The Messy Art of Balancing the Elegant and the Practical in Industrial Software

We review common issues in transitioning mathematical software from research grade projects into products that are used and useful, as gleaned from our work in the pipeline industry. Mathematical elegance can equate with practicality, but only if it is unveiled at the right time under the right conditions. Mixed integer NLP algorithms for compressor unit selection, nonserial dynamic programming for network optimization, and algorithms for transient pipeline optimization can be used to illustrate these issues.

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MS14

Computational Sciences for Oil and Gas Exploration and Production Research

Hydrocarbon exploration and production faces significant computational challenges. Although information about the subsurface can be gleaned from seismic imaging, well logging, and fluid production history, ultimately we need modeling to evaluate and optimize the economic returns on oil and gas investments. Successful commercialization of these modeling technologies requires integration of high-end computational sciences with software development technologies. I illustrate with examples of ExxonMobil proprietary modeling products.

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MS14

Comfort Estimation and Incentive Design for Energy Efficiency

The comfort of the occupants of a building depends on many factors including metabolic rates, clothing, air temperature, mean radiant temperature, air velocity, humidity, lighting and noise. Here, we describe a methodology to provide incentives to the occupants of a building in order to be more energy efficient. We develop a method to estimate the comfort inter-relations among occupants by combining various methodologies developed in social network analysis, statistics and economics. This technique is then used to design the incentives to encourage energy efficient behavior.

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MS14

Mathematics in the Development of Biomarkers and Therapeutics

We describe examples of the application of mathematics to the development of therapeutics and biomarkers. A biomarker is defined as an indicator of a biological state. It is a characteristic that is objectively measured and evaluated as an indicator of normal pharmacologic responses to a therapeutic intervention.

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MS15

Investigating Graph Operations on Gpu Architectures

GPUs have become an integral component in many areas of scientific computing , however, it is challenging to efficiently map operations on graphs, representable as sparse matrices, to GPUs. The data-driven, highly irregular, low computational intensity and poor locality of many graph operations requires algorithmic reformulation and implementation which mitigates the negative impact of these operations on the memory subsystem and utilize efficient parallel primitives which are amenable to the SIMD machine model. Using breadth-first search (BFS) as the archetype of graph operations on GPUs we will discuss maximal independent sets and graph partitioning.

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MS15

Matrix Transversals on GPUs

We design, implement, and evaluate algorithms for finding maximum cardinality matchinge in bipartite graphs on GPUs. To the best of our knowledge, ours is the first study that provides a GPU implementation and a through evaluation. Our motivating application lies in the solutions of sparse linear systems. We compare our algorithms with existing sequential and multicore implementations on many real-life matrices where in majority of the cases the GPU-accelerated algorithm is much faster.

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MS15

Parallel Algorithms for Matching Graphs on Multicore Computers

We discuss recent work on developing parallel algorithms for computing edge-weighted matchings in graphs on multicore computers. An algorithm that includes locally heavy edges in the matching is known to provide a half-approximation to the weighted matching problem. We evaluate this algorithm on multicore machines using a shared memory programming paradigm. We show that exploiting the structure of a bipartite graph can lead to faster computation of matchings on multicore machines.

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MS15

Computing Strongly Connected Components in Modern Architectures

Finding the strongly connected components of a directed graph is a fundamental graph problem. For example, it is part of computing the block triangular form of a sparse matrix. Tarjan's algorithm is an efficient serial algorithm, but relies on depth-first search which is hard to parallelize. The parallel algorithm by Fleischer et al. uses divide-and-conquer, but has only been evaluated on distributed memory systems. We develop multithreaded versions and compare several variations of this algorithm.

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MS16

An Incremental SVD for Feature Extraction from Fluid Flow

The dynamic mode decomposition approximates the evolution operator of a physical system via a few dominant modes. These modes are computed from experimental snapshots, without relying on the mathematical description of the system. However, these snapshots are expensive to acquire and store, and the modes are expensive to compute. We present a new algorithm, based on the Low-Rank Incremental SVD. This algorithm approximates the dynamic modes in an online manner, with significant computational savings.

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MS16

Randomized SVD Methods in Hyperspectral Imag-

ing

We present a randomized singular value decomposition (rSVD) method for the purposes of lossless compression, reconstruction, classification, and target detection with hyperspectral (HSI) data. Recent work in low-rank matrix approximations obtained from random projections suggests that these approximations are well suited for randomized dimensionality reduction. Numerical results on HSI will be presented.

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MS16

Truncated Tensor-SVD Methods for Facial Recognition

Recent work on tensor-tensor decomposition by Kilmer and Martin has lead to tensor factorizations reminiscent of rank-revealing matrix factorizations. In this work, we discuss the application of the truncated tensor SVD to the facial recognition problem. Comparisons with traditional matrix-PCA and TensorFaces show our method has the potential for superior compression for a fixed recognition rate, among other advantages.

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MS16

Applications of a Symmetry Preserving SVD

Knowing information about structural symmetry is advantageous in many SVD applications. For example, in protein dynamics, determining symmetry allows one to provide SVD major modes of motion that best describe the symmetric movements of the protein. In facial recognition, symmetry in the SVD allows for more efficient compression algorithms. This talk will concentrate on constructing such an SVD which preserves symmetry inherent in the data via a symmetry preserving singular value decomposition (SPSVD).

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MS17

Hierarchical Structure and Predictability of the Madden Julian Oscillation from Infrared Brightness Temperature Data

The convection-coupled tropical atmospheric motions are highly nonlinear and multiscaled, and play a major role in weather and climate predictability in both the tropics and mid-latitudes. In this work, nonlinear Laplacian spectral analysis (NLSA), a manifold generalization of PCA, is applied to extract spatiotemporal modes of variability in tropical dynamics from infrared brightness temperature satellite data. The method reveals a wealth of spatiotemporal patterns, including the Madden-Julian oscillation and its interaction with diurnal convective processes.

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MS17

Uncertainty Quantification in Ocean State Estimation

A Hessian-based method is developed for Uncertainty Quantification in global ocean state estimation and applied to Drake Passage transport. Large error covariance matrices are evaluated by inverting the Hessian of a model-observation misfit functional. First and second derivative codes of the MIT general circulation model are generated by algorithmic differentiation and used to propagate the uncertainties between observation, control and target variable domains. The dimensionality of the calculations is reduced by eliminating the observation null-space.

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MS17

Uncertainty Predictions, Non-Gaussian Data Assimilation and Bayesian Inference of Dynamical Model Equations

Abstract not available at time of publication.

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MS17

Bayesian Hierarchical Model Applications in Ocean Forecasting

Ensemble surface winds and ensemble surface stresses are obtained from Bayesian Hierarchical Models, given data stage inputs from satellites and weather-center analyses. Process model distributions are based on leading order terms from a Rayleigh Friction Equation balance and from formulae for bulk transfers. The forcing ensembles exploit precise observations and precise specifications of error to infer error in ocean forecasts based on two different kinds of data assimilation (DA) systems; i.e., a sequential DA system in the Mediterranean Sea and a variational DA system in the California Current System.

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MS18

Particles at Fluid-Fluid Interfaces: A New Navier-Stokes-Cahn-Hilliard Surface Phase-Field Crystal Model

Colloid particles that are partially wetted by two immiscible fluids can become confined to fluid-fluid interfaces. At sufficiently high volume fractions, the colloids may jam and the interface may crystallize. The fluids together with the interfacial colloids form an emulsion with interesting material properties and offer an important route to new soft materials. We develop an improved Navier-Stokes-Cahn-Hilliard-Surface-Phase-Field-Crystal model based on the principles of mass conservation and thermodynamic consistency. To validate our approach, we derive a sharp interface model and show agreement with the diffuse interface model. We demonstrate jamming and the solid-like behaviour of the crystallized interface by simulating the fall of a solid ball through a colloid-laden multiphase fluid.

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MS18

Diffusion Driven Instabilities on Evolving Surfaces

Reaction diffusion systems defined on evolving surfaces has many application in mathematical biology. Examples of such applications include tumor growth, pattern formation on seashells, butterfly wing pigmentation patterns and animal coat markings. We develop and analyze a finite element method to approximate solutions of nonlinear reaction diffusion systems defined on evolving surfaces. The method we propose is based on radially projected finite elements.

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MS18

A Phenomenological Model for Cell Migration and Deformation: Application to the Immunity Response

We simulate the immune response system incorporating cell deformation. We model leukocyte transport through small blood vessels (SBV), as a result of acidity resulting from infecting bacteria. The leukocytes leave the SBV by vessel wall-penetration and enter the surrounding tissue where they neutralize bacteria. The model combines stochastic processes, SDEs, PDEs and temporal displacement of surfaces.

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MS19

Parametric Model Reduction for Bousinesq Equations

A number of applications, such as uncertainty quantification, require multiple numerical simulations of a PDE within a narrow parameter range. Brute force simulation is not suitable for complex simulations and model reduction methods are an attractive option. We discuss several strategies for improving model reduction of the Boussinesq equations by combining sensitivity analysis, sampling strategies, and selecting appropriate time windows for computing POD bases. The stability of these resulting models will also be discussed.

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MS19

Consistent Vorticity Boundary Conditions for a Velocity-Vorticity Splitting Method

We derive boundary conditions for vorticity, if we are given that velocity is no-slip, in the context of a velocity-vorticity splitting algorithm for approximating solutions to the Navier-Stokes equations. We show numerically this allows for optimal convergence, and test of several benchmark problems.

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MS20

Humans Make Suboptimal Decisions in Face of Structured Input

It is unclear whether the principle of Bayesian optimality can describe perception of visually structured inputs. To address this question, we examined whether humans take into account spatial correlations when detecting a target among a group of distractors. Varying correlation strength between distractors changed the amount of structure. We found that subjects were suboptimal - humans were not able to infer the correct correlation structure, but appear to see structure even when there is none.

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MS20

Parallel and Approximate Methods for Solving Eikonal Equations

The Eikonal PDE

$$|\nabla u(\mathbf{x})|\mathbf{F}(\mathbf{x}) = \mathbf{1}, \text{ on } \mathbf{\Omega} \subset \mathbf{R^n};$$

$$u(\mathbf{x}) = \mathbf{q}(\mathbf{x}), \text{ on } \partial\mathbf{\Omega}.$$

can be interpreted as an equation for the time-of-arrival function $u(\mathbf{x})$ from a point $\mathbf{x}$ to the boundary of the domain Ω by following the (a priori unkown) optimal path under a given speed function $F(\mathbf{x})$. This is a type of Hamilton-Jacobi equation and thus solutions are generally non-smooth. A system of coupled nonlinear equations results from approximating the value function u by first-order upwind finite differences. Nowadays there are several efficient algorithms for solving the Eikonal equation. I will spend the first half of the talk reviewing and comparing various state-of-the-art methods. In the second half of the talk, I focus on the problem of solving the Eikonal equation at one point instead over all of Ω. Efficiently computing the solution has been accomplished using various approximate methods and heuristic accelerations to prior methods, but all are missing a rigorous error quantification. I will present new rigorous error bounds for specific approximate methods. This is joint work with Zachary Clawson and Alex Vladimirsky.

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MS20

Modeling and Computations for Multi-scale Eddy Current Problems

In this paper, we study the nonlinear Maxwell equations with laminated conductors. Direct simulation of three-dimensional (3D) eddy currents in grain-oriented (GO) silicon steel laminations is very challenging since the system has multiple sizes and the magnetic reluctivity is nonlinear and anisotropic. We proposed a new eddy current model which omits micro scales and thus reduces the scale ratio. The new model is validated by finite element computations of an engineering benchmark problem—Team Workshop Problem 21c-M1.

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MS20

A Study of the Cochlea Using the Immersed Boundary Method

This talk studies the cochlea (inner ear) using the immersed boundary (IB) method where the basilar membrane is represented by the immersed boundary. To model the sound amplification ability of the cochlea, we include a parametric forcing via the elastic stiffness of the membrane. A Floquet analysis of the linearized equations is presented that suggests the existence of parametric resonance. Numerical simulations of the full IB equations are performed to verify the Floquet analysis.

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MS20

Finite Element Methods for the Evolution Problem in General Relativity

Einstein's equations of General Relativity, the equations that describe how space and time bend in the presence of masses, cannot be solved analytically except under special circumstances. Thus numerical calculations are essential in predicting what these changes might look like. But computer simulations have themselves proven very challenging.

I have expanded the application of the finite element methods to General Relativity, by adapting the recently developed Finite Element Exterior Calculus framework. The resulting numerical method is the first computer implementation of the Electric-Magnetic formulation, producing simulations for General Relativity from a new perspective.

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MS20

Survival Analysis on Patients with Chronic Hepatitis B: Modeling the Onset of Liver Cancer

Using survival analysis, we model the onset of liver cancer in Taiwanese patients with chronic hepatitis B. We construct time-independent and time-dependent proportional hazards models and compare using residual analyses and information criteria scores. We demonstrate that our model treating liver cirrhosis as a time-dependent covariate performs better than time-independent models. We conclude that monitoring and early diagnosis of liver cirrhosis in hepatitis B patients can be crucial in preventing the onset of liver cancer. Advisor Dr. Ke Wu, California State University, Fresno. Conducted as part of the 2012 REU in Mathematics at California State University, Fresno.

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MS21

AMG Preconditioning for Embedded Uncertainty Quantification

In this talk we consider algebraic multigrid (AMG) preconditioning for systems arising from stochastic Galerkin methods for uncertainy quantification. In particular, we will consider various AMG approaches for solving block structured systems whose degrees of freedom are ordered such that each individual block's sparsity corresponds to the stochastic discretization and the outer sparsity is that of the deterministic PDE. We provide numerical studies and give an overview of the software underpinning this effort.

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MS21

Reducing Communication in Algebraic Multigrid

Algebraic Multigrid (AMG) solvers are an essential component of many large-scale scientific simulation codes. Their continued numerical scalability and efficient implementation is critical for preparing these codes for emerging computer architectures. Previous investigations have shown that the increasing communication complexity on coarser grids combined with the effects of increasing numbers of cores lead to severe performance bottlenecks for AMG on various multicore architectures. We will discuss several efforts to reduce communication in AMG, including the use of agglomeration, redundancy as well as additive approaches.

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MS21

On Parallelization of an Energy Minimizing Multigrid

The linear systems arising from multi-physics simulations may challenge traditional algebraic multigrid (AMG) solvers. AMG methods based on energy minimization prove to be an effective approach. They contain two components: an a priori chosen nonzero pattern of a prolongator, and interpolation of low energy modes; both act as constraints in an optimization problem. In this talk, we discuss a parallel implementation, challenges of solving the constrained problem, and the performance of energy minimization AMG.

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MS21

AMG Shifted Laplacian Preconditioners Viewed Through Chebyshev Polynomials

In this talk, we will provide some motivation for using the Shifted Laplacian preconditioner in indefinite Helmholtz problems with analysis of Chebyshev polynomial smoothers. We will attempt to give some reasoning to the choice of the complex shift parameter in the preconditioner. In conclusion, we will show some numerical results of using smoothed-aggregation algebraic multigrid for the Shifted Laplacian, applied to examples in structural dynamics.

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MS22

Your Career Trajectory

What are the types of influences on your career path - and what can you do to stay on your chosen trajectory? Online advice includes: “be proactive, not reactive”. More realistic is: “be both proactive and reactive” depending on the situation. Advancing, improving, developing - and altering: all likely have their place at some time as we blend, or separate, our work and personal lives.

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MS22
My Life as a Mathematician

Abstract not available at time of publication.

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MS22
Sometimes Good Things Happen

Abstract not available at time of publication.

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MS22
More Than Survive-We Want to Thrive!

Say you have landed a postdoc or tenure-track position, now what? What do you need to do in order to succeed? How should you choose your research directions? What about networking? How can you be a successful teacher without spending all your time preparing for lectures? How much time should you devote to administrative duties? And how and when should you say no? How do you balance work and family?

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MS23
Application of a Comprehensive Second-Order Near-Field Interferometric Sar (insar) Model to the Terrain Retrieval Problem at W-Band (with Lidar Validation)

We describe a near-field extension of the canonical far field spotlight SAR image model and the corresponding InSAR terrain retrieval model. The model extends the far field model to regions of significant wavefront curvature and accounts for interaction between wavefront curvature effects and SAR aperture non-planarity. The extended InSAR model has been successfully applied to W-band SAR data collected by Aerospaces 95GHz rail SAR. Results are validated by comparison with ground based LIDAR.

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MS23
Cloud Benchmarking: The Ongoing Evolution of Computer System Evaluation

The Cloud Tester Benchmark Suite (CTBS) is a set of tools for the standardized benchmarking of computer system performance within Cloud Infrastructure-as-a-Service environments which are quickly becoming the standard at a variety of organizations, including The Aerospace Corporation. The CTBS currently captures standard computer system performance information along with on-demand features new to the cloud. This talk will present the CTBS and its use to guide appropriate server selection in virtualized on-demand computing systems.

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MS23
Design of the Advanced EHF-1 Orbit Transfer

Two days after launch, in August 2010, the feed system for the Advanced EHF-1 satellites liquid apogee engine (LAE) malfunctioned, stranding the spacecraft in its initial transfer orbit. Building on optimal control theory used for the pre-anomaly transfer design, mission analysts at The Aerospace Corporation developed a low-thrust transfer concept that was more fuel-efficient than the original, time-optimal design. This presentation reviews the principal tools, theory, and mission trades involved in redesigning the orbit transfer.

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MS23
Lunar Imaging with Synthetic Aperture Radar

We describe the use of the Goldstone Solar System Radar (GSSR) to make Earth-based interferometric maps of the southern lunar surface. Using Interferometric Synthetic Aperture Radar (InSAR) to form image pairs from 90 minute apertures, we produce topographic maps with horizontal resolution of 40 m and vertical height accuracy of 4 m. Long apertures and orbital mechanics dictate that in addition to the usual problems of image registration and solution of the interferometric equations, novel space-variant autofocus techniques were developed.

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MS24
Numerical Study of Hybrid Block Pseudospectral and Radial Basis Function Method for PDE

We numerically investigate a hybrid technique based on BPS and RBF to address partial differential equations whose solutions are smooth, but exhibit localized features.

The implementation of the algorithm is similar to overlapping grid method, where BPS grids are used as background grid and RBF nodes are concentrated in high activity regions. The two methods are coupled through penalty-type coupling. Numerical experiments in solving time-dependent collocation problems will be shown.

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MS24
An Adaptive RBF-WENO Reconstruction Method

We present an adaptive RBF-WENO method using the multi-quadric RBFs for the local reconstruction. The method is that the shape parameters are adaptively determined based on the regularity of the local reconstruction in each stencil. By this flexibility, the reconstruction can enhance accuracy and convergence although using polynomials in each stencil allows only a fixed convergence rate. We construct the ENO and then WENO reconstructions and show how the accuracy is enhanced with numerical examples.

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MS24
A Radial Basis Functions Method for Solving Fractional Diffusion Equations

Diffusion processes in complex systems are often observed to deviate from standard laws and are poorly represented by second-order diffusion models. Such deviations are observed in as diverse contexts as stock market volatility or random displacements of living species in their search for food. An ongoing issue with fractional diffusion models is the design of anefficienthigh-order numerical discretization. We will show that RBFs are exceptionally suited for this problem.

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MS24
Application of Fredholm Integral Equations Inverse Theory to the Radial Basis Function Approximation Problem

The relationship between the solution and stability of Fredholm integral equations and radial basis function approximation or interpolation is discussed. Underlying system matrices have a smoothing property dependent on the kernel. Techniques from inverse theory are useful for interpreting and mitigating instability. Numerical results demonstrate that interpolation weights may be regarded as samplings of a weighted solution of an integral equation which is relevant for mapping between the centers of radial basis functions.

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MS25
Nesting ROMS and UCOAM: A Case Study in Monterey Bay

The Regional Ocean Modeling System (ROMS) is a hydrostatic free-surface ocean model ideally suited to simulate medium to large-scale coastal ocean processes. The Unified Curvilinear Ocean Atmosphere Model (UCOAM) is a non-hydrostatic LES model designed specifically for high-resolution simulations, and is capable of accurately reproducing the interaction of currents with steep bathymetric features. In this study, non-hydrostatic UCOAM is nested within ROMS, and the nested model is used to study realistic currents in Monterey Bay.

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MS25
Distributed Coupling Toolkit

The Distributed Coupling Toolkit (DCT) is a library to couple multi-physics and multi-resolution models in a truly distributed manner. The DCT has a user-friendly interface to formulate the coupling of variables and fields within pairs of model components. DCT distributed approach guarantees scalability both at the model complexity and parallel processing levels. The DCT is used to weakly couple different components of The General Environmental Coastal Ocean Modeling (GECOM). We present some new capabilities implemented in DCT and we show some performance results of using DCT.

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MS25
A Cyberinfrastructure-Based Computational Environment for General Environment Coastal Ocean (GECOM) Models

GECOM models require lengthy simulations, sub-km scale meshes (10^{10} cells), and TBytes of data. To facilitate running simulations, we have developed a computational environment (CE) that includes a parallel, MPI framework that runs on distributed, heterogeneous resources, and computational services based on the Cyberinfrastructure Web Application Framework (CyberWeb). CyberWeb capabilities include: user accounts; authentication; task execution, management, and history; data management; and visualization. In this talk we discuss our experiences in developing the GECOM CE and community portal.

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MS26

Sharp Estimates on the Magnetic and Pauli Spectra of Plane Domains

We investigate sharp upper bounds on spectral functionals of the magnetic Laplacian (for a particle without spin) and the Pauli operator (a particle with spin), on convex and starlike plane domains. Our results cover the first eigenvalue, spectral zeta function, partition function, and more. The geometric normalization involves moment of inertia, area, and a natural log-L^2 measure of the roughness of the boundary.

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MS26

Adjoint-Based Photonic Design: Optimization for Applications from Super-Scattering to Enhanced Light Extraction

Adjoint-based optimization techniques are fast and efficient methods for exploration of large design spaces. We employ them towards photonic design problems; in particular, we present applications in super-scattering from metallic nano-particles, as well as enhanced light extraction from two-dimensional thin films. For the scattering problem, we exploit contour integration to transform the frequency-averaged scattering to a single, complex-frequency computation. This yields significant performance benefits and enables faster and more efficient optimal design.

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MS26

Optimization of Plasmon Resonances of Nanoparticles

This talk is concerned with plasmon resonances of metallic nanoparticles. We show that these values are the complex eigenvalues of Maxwell's equations that only occur when the dielectric permittivity of the nanoparticles is negative, and the ratio δ between the size of the nanoparticles and the incident wavelength is small enough. Afterward, we prove that the resonances satisfy a nonlinear spectral problem on the boundary of the nanoparticles. Using Fredholm theory and the generalized Rouché Theorem we derive the complete asymptotic of the plasmon resonances as the parameter δ tends to zero. The asymptotic expansion is then used in a second step to optimize the plasmon resonances with respect to the shape, and the inter-distance between the particles.

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MS26

Waves in Honeycomb Structures

Abstract not available at time of publication.

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MS27

A Cluster-Cluster Treecode Algorithm

We present a new Cartesian treecode algorithm that uses both far-field and near-field multipole expansions unlike the standard treecode algorithms which use only one kind of expansion. The algorithm eliminates the need for repeated computation of Taylor series coefficients in iterative simulations and it's shown to be more efficient for medium accuracy requirements in test problems in computational chemistry.

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MS27

A Parallel Adaptive Treecode for Evolution of Microstructure in Elastic Media

We describe an O(N logN) adaptive treecode for elastostatics computation. The code is tested both with randomly generated data and in a spectrally accurate method for materials science problems. We also present a parallelized version of the treecode. The new version is relatively easier to implement, because it entails less communication between processors. We show that the parallel version scales linearly for a moderate number of processors for both uniform and non-uniform data.

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MS27

Gpu and Treecode Accelerated Electrostatics Com-

putation for Implicitly Solved Biomolecules

We present a treecode-accelerated boundary integral (TABI) solver for electrostatics of solvated biomolecules. The method employs a well-conditioned boundary integral formulation. The surface is triangulated and the integral equations are discretized by centroid collocation. The linear system is solved by GMRES iteration and the matrix-vector product is carried out by a Cartesian treecode which reduces the cost from $O(N^2)$ to $O(N \log N)$ for N boundary elements. We also present parallel TABI simulations on GPUs.

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MS27

A Treecode for Fast Summation of Matern Covariance Kernels

Evaluating sums of multivariate Matern kernels is a common computational task in statistical and machine learning community. The quadratic computational complexity of the summation is a significant barrier to practical applications. We develop a Cartesian treecode algorithm to efficiently estimate sums of the Matern Kernel. The method uses a far-field Taylor expansion in Cartesian coordinates to compute particle-cluster interactions. The Taylor coefficients are obtained by recurrence relations which allows efficient computation of high order approximations. In the serial code, for a given order of accuracy, the treecode CPU time scales as $O(N \log N)$ and the memory usage scales as $O(N)$, where N is the number of particles. Parallel code also gives promising scale.

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MS28

An Industrial Perspective on Global Optimization

Global optimization is the goal of almost every user in aerospace design but among the most difficult goals to realize. We discuss some of our experience with global optimization algorithms on industrial problems. In particular, for problems with more than a handful of variables, we have found the most success by applying a version of the algorithm of Rinnooy Kan and Timmer, modified to handle nonlinear constraints. We discuss some of our successes and failures and propose some open areas of research that we are interested in.

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MS28

High-Resolution Bathymetry Using 8-Band Multispectral Imagery from WorldView-2

DigitalGlobes WorldView-2 satellite has eight high-resolution spectral sensors onboard that can be exploited for shallow water bathymetry (i.e., measuring the water depth in shallow waters) and identifying benthic habitats. We have enhanced WorldView-2s water depth retrieval by improving the speed and accuracy of bathymetric calculations on high resolution imagery. This presentation will introduce the shallow water bathymetry application and discuss some recent algorithmic advances for solving this large inverse problem.

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MS28

Stochastic Optimization for Model Mis-specification Mitigation

Numerical simulation is instrumental for description, prediction, control and design of complex systems. Fidelity of the simulation process plays a central role in attainment of meaningful predictive capabilities. Frequently, the simulation model is mis-specified to a certain extent. Such misspecification may originate from incomplete or approximated physical description of the problem (i.e. governing equations, geometry, boundary conditions, input model parameters, etc.), the use of approximated numerics (i.e. floating point round-off error, truncated expansions, discretization error, numerical approximation, etc.), linearization of non-linear processes, or any other unknown sources of modeling error. In this study, we supplement a mis-specified observation model by a low rank addition. For that purpose a nuclear norm stochastic optimization technique was developed. We demonstrate the utility of the approach for ill-posed imaging problems.

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MS28

Improved Estimation of the T2 Distribution from Nmr Measurements

The inversion of the relaxation distribution from NMR data is a non-unique and ill-conditioned problem. It is often solved in the literature by finding the smoothest solution that fits the measured data by use of regularization. In this paper, we modify this algorithm by further constraining it with linear functionals of the solution that can be directly estimated from the measured data. We find that the new algorithm provides better estimates of the solution.

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MS29

A Multi-class Dynamic Assignment Approach to Traffic and Event Management

To aid decision making in planning for everyday and special events, the City of Vancouver developed the Downtown Vancouver Emergency and Transportation Management System (DVTEMS). DVTEMS is a multi-modal dynamic traffic assignment model with a specific focus on pedestrian behavior and route choice. DVTEMS explicitly models changing demand and network conditions and can represent traffic flow in a far more accurate manner compared to the conventional regional planning model using static traffic assignment.

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MS29

Empirical and Experimental Studies on Uninterrupted Traffic Flow

The systematic investigation of traffic flow behavior has quite a long history. Many interesting traffic phenomena have been observed. For example, capacity drop, phantom jam, the wide scattering of data in the flow-density plane in congested flow. However, there is still many controversies in this field, mainly due to lack of traffic flow data. In this presentation, I will present some results of our empirical observations and car-following experiment.

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MS29

Starting Wave in a Queue of Pedestrians and an Analogy with Compressible Fluid Flow

"Slow-in Fast-out" is the keyword to resolve the queue. Starting wave, which is a wave of people's successive reactions in the relaxation process in a queue, has an essential role for pedestrians and vehicles to achieve the fast-out strategy. Moreover, starting wave is assumed as a sonic wave in the fluid dynamics. In this talk, the analogy between the starting wave in a queue and the sonic wave in the fluid will be presented.

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MS29

Cellular Automata and Pedestrian Dynamics

Many collective phenomena in pedestrian dynamics have been modeled, simulated, and theoretically analyzed by applying cellular automata so far. In this talk three examples are presented. Firstly, it is shown that an obstacle which is appropriately set near an exit may decrease the total evacuation time. Secondly, a new designing method for large queuing system is introduced. Thirdly, a method for improving pedestrian flow by imposing a rhythm is proposed.

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MS30

Strategies for Calibration of Large-Scale Climate Models

Computer model calibration is the process of determining input parameter settings to a computational model that are consistent with physical observations. This is often quite challenging due to the computational demands of running the model. This talk will show how the Ensemble Kalman filter (EnKF, Evensen 2009) can be used for computer model calibration. It is motivated by the mean and covariance relationship between the model inputs and outputs, efficiently producing posterior ensemble of the calibration parameters. While this approach may not fully capture effects due to nonlinearities in the computer model response, its computational efficiency makes it a viable choice for exploratory analyses, design problems, or problems with large numbers of model runs, inputs and outputs. An example in which parameters from the Community Atmosphere Model.

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MS30

Application of Polynomial Chaos Methods to Ocean Modeling

Abstract not available at time of publication.

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MS30

Distilling Regional Climate Model Data from Narccap for Use in Impacts Analysis

The North American Regional Climate Change Assessment Program (NARCCAP) is an international, multi-institution collaboration to simulate climate change over North America using high-resolution regional models. The data archive for NARCCAP is more than forty terabytes in size and includes more than fifty variables. As data providers, to make these results usable by impacts users and other non-specialists, we need to do more than just publish the raw model output; we need to encapsulate our knowledge and understanding of the models by providing

derived data products that are well-matched to end-user needs. In this talk, I will discuss some of the complicating factors that make bias-correction, regridding and interpolation, and climatology creation more difficult than may be expected, and the statistical methods that we use in generating derived data products. I will aso cover some lessons learned about the practicalities of archiving large datasets, and the implications of these issues for data analytics and publishing as we move into the era of big data.

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MS30

Model Error Analysis: Uncertainty Inherent in Model Physics Parameterizations

Uncertainty in model parameterizations is a primary source of forecast error in weather and climate prediction. In this presentation, a Markov chain Monte Carlo algorithm is used to examine the relationship between model parameter uncertainty and the convective scale dynamics and environment. We find that constraint of microphysical parameters with observations uniquely determines many aspects of the deep convective structure. Where this is not the case, the results indicate which additional observations may be required.

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MS31

Waveform-Diverse Moving-Target Synthetic-Aperture Radar

Abstract not available at time of publication.

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MS31

Interferometric Waveform Inversion

In synthetic aperture radar imaging, fitting cross-correlations of wavefields rather than the wavefields themselves can result in improved robustness vis-a-vis model uncertainties. This approach however raises two challenges: (i) new spurious local minima may complicate the inversion, and (ii) one must find a good subset of cross-correlations to make the problem well-posed. I will explain how to address these two problems with lifting, semidefinite relaxation, and expander graphs. This mix of ideas has recently proved to be the right approach in other contexts as well, such as angular synchronization (Singer et al.) and phase retrieval (Candes et al.). Joint work with Vincent Jugnon.

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MS31

Geometry of SAR Imagery

Abstract not available at time of publication.

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MS31

Challenges in Advanced Moving-Target Processing in Wide-Band Radar

In this talk we will describe real-world challenges for detecting and tracking moving targets in wideband synthetic aperture radar (SAR) data containing strong background clutter returns.

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MS32

Deconvolution-Based Indicator Functions in Nonlinear Filters for Regularization Models

We study a trapezoidal-in-time, finite-element-in-space discretization of a new Leray regularization model that locally chooses the filtering radius using a deconvolution based indicator function to identify regions where regularization is needed. Because this indicator function is mathematically based, it allows us to establish a rigorous analysis of the resulting numerical algorithm. We prove well-posedness, unconditional stability, and convergence of the proposed algorithm, and test the model on several benchmark problems.

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MS32

Efficient Augmented Lagrangian-type Preconditioning using Grad-Div Stabilization

Grad-Div stabilization can be exploited in a preconditioner for the Oseen Problem. It turns out that it behaves similar to the classical augmented Lagrangian approach, but with the advantage of being able to easily construct the system matrix efficiently. This simplifies the construction of inner preconditioners. I will discuss the difficulty of the trade-off between solution accuracy from stabilization and solver efficiency. Finally, I will present numerical results to demonstrate the robustness preconditioner.

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MS32

Validation of An Open Source Framework for the Simulation of Blood Flow in Rigid and Deformable Vessels

We discuss the validation of an open source framework for the solution of problems arising in hemodynamics. The framework is assessed through experimental data for steady flow in an idealized medical device with rigid boundaries and a numerical benchmark for flow in compliant vessels. The core of the framework is an open source parallel finite element library that features several algorithms for fluid and fluid-structure interaction problems. A detailed account of the methods is provided.

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MS32

Nonlinear Reduced Order Modeling of Complex Flows

The reduced-order models (ROMs) are frequently used in the simulation of complex flows to overcome the high computational cost of direct numerical simulations, especially for three-dimensional nonlinear problems. The proper orthogonal decomposition (POD), as one of the most commonly used tools to generate ROMs, has been utilized in many engineering and scientific applications. Its original promise of computationally efficient, yet accurate approximation of coherent structures in high Reynolds number turbulent flows, however, still remains to be fulfilled. To balance the low computational cost required by ROMs and the complexity of the targeted flows, appropriate closure modeling strategies need to be employed. In this talk, we put forth several closure models for the POD-ROMs of structurally dominated turbulent flows. These models, which are considered state-of-the-art in large eddy simulation, are carefully derived and numerically investigated. We also discuss several approaches for an efficient and accurate numerical discretization of general nonlinear POD closure models. We numerically illustrate these developments in several computational settings, including a three-dimensional turbulent flow past a cylinder at Reynolds number Re = 1000. A rigorous numerical analysis of the new computational framework will also be presented. or

other high-level commands. Do not include references or citations separately at the end of the abstract. Instead, all citations must be in text in the general form [Authorname, Title, etc]

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MS33

A Hamilton-Jacobi Equation for the Continuum Limit of Non-dominated Sorting

Non-dominated sorting is a fundamental problem in multi-objective optimization, and is equivalent to several important combinatorial problems. It is used, for instance, to combine results from multiple search engines, or retrieve images from a database that are similar to multiple queries. We prove that non-dominated sorting of random points in Euclidean space has a continuum limit that corresponds to solving a Hamilton-Jacobi equation. I will describe this result and give some theoretical and practical applications.

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MS33

Modeling Immunotherapy of the Tumor - Immune Interaction

Cancer is still a leading cause of death, and years ago a model was proposed by Kirshcner and Panetta to analyze a particular type of treatment of cancer. Starting with some fundamental biological concepts, we explore their proposed system used to explain the immunotherapy of the tumor by reviewing their system of ordinary differential equations, and contemplating their results.

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MS33

Wavelet Frame Based CT Image Reconstructions

X-ray computed tomography (CT) has been widely used in diagnosis of cancer and radiotherapy. However it is important to reduce the radiation dose as low as reasonably achievable because the x-ray radiation is harmful to the patients. Moreover, the interior tomography which illuminate a region-of-interest (ROI) can save the radiation dose.

Two robust wavelet tight frame based CT reconstruction methods will be introduced for both global reconstruction and interior tomography to reduce the error caused by mechanical inaccurate execution of the huge sparse projection matrix. Numerical simulation results show that our proposed analysis based approach can apparently outperform all the popular methods in terms of both the visual qualities and mean structural similarity. Additionally, our proposed synthesis based approach can preserve most useful tiny features and suppress the noise and artifacts.

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MS33

The Flag of Best Fit as a Representative for a Collection of Linear Subspaces of $\mathbf{R}^n$

Simple object recognition often requires the computation of averages or exemplars for sets of labeled samples. When the sets of labeled samples are point clouds on a Grassmann manifold, the most common average used is the Karcher mean. We present a new average for data that can be represented by points on a Grassmannian, called the flag mean, and compare it to other averages in the literature.

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MS33

Higher Order Fréchet Derivatives of a Matrix Function and Applications

The natural derivative for matrix functions is the Fréchet derivative $L_f(A, E)$. The Fréchet derivative is useful in optimization and image registration, also being used to define the condition number (sensitivity of f to perturbation in A). We describe higher order Fréchet derivatives and some applications: the conditioning of $L_f(A, E)$ and the level-2 condition number of a matrix function. The latter shows some very interesting behaviour that is not yet fully understood.

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MS33

A Globally Convergent Numerical Method for Optical Tomography Inverse Problem

In our terminology "globally convergent numerical method" means a numerical method whose convergence to a good approximation of the correct solution is independent of the initial approximation in inverse problems. A numerical imaging algorithm has been proposed to solve a coefficient inverse problem for an elliptic equation and then the algorithm is validated with the data generated by computer simulation.

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MS34

A Spectral Analysis for Linear-Transform based Regularizations

Regularization is a widely used technique to incorporate prior information into mathematical models to favor desired solutions. Whencomputingpiecewise polynomial solutions whose derivative of a certain order are sparse, acommonregularizer is the L1 norm of the derivative. This study is motivated by the observation that approximations to the desired solution are often far more accurate, sometimes up to orders of magnitude, than approximations to the sparse derivatives. We explain such a phenomenon by a spectral analysis of discrete derivative operators. Based on the understanding gained, we propose alternative regularizers to enhance finite difference regularizers.

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MS34

Data Assimilation for Parameter Estimation in Coastal Ocean Hydrodynamics Modeling

Coastal ocean models are used for a variety of applications, including modeling tides and hurricane storm surge. These models numerically solve the shallow water equations, which are derived by depth integrating the Navier-Stokes equations. One significant source of uncertainty in these models is poorly known bottom friction. In this work we will estimate bottom friction using statistical data assimilation methods.

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MS34

Optimizing Treatment Regimes to Hinder Antimicrobial Resistance in Pandemic Influenza Across Time Scales

The large-scale use of antimicrobials during influenza pandemics posses a significant selection pressure for drug-resistant pathogens to emerge and spread in the population. This requires treatment strategies to minimize total infections as well as the emergence of resistance. Here we propose a mathematical model in which individuals infected with a wild-type strain, if treated, can develop de novo resistance and further spread the resistant pathogen. Our main purpose is to explore the impact of two important factors influencing the effectiveness of treatment strategies: i) the relative transmissibility of the drug-resistant strain, and ii) the likelihood of de novo resistance occurrence. For the long-term scenario, we find a condition between these two parameters that indicates whether treatment regimes will be most beneficial at intermediate or more extreme values. Moreover, we present analytical expressions for effective treatment regimes and provide evidence of its applicability across time scales.Therefore, our results provide long- and short-term insights for the control of drug-resistance in influenza pandemics.

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MS34

Curvature-dependent Surface Tension in Modelling of Fracture

A new model of fracture mechanics which takes into account interfacial effects due to a curvature-dependent surface tension will be considered. This model is based on a physically valid assumption that the behavior of molecules near a surface of a material is significantly different from those in the bulk and depends on the local curvature of the material surface. The theory will be presented through three examples: a curvilinear non-interface crack, a straight interface crack and contact problems for a rigid stamp indentation into an elastic half-plane. It will be shown that the incorporation of surface effects on the crack boundary will eliminate the power and oscillating singularities at the crack tips which are predicted by linear elastic fracture mechanics. The mechanical problems will be reduced to the systems of singular integro-differential equations. The regularization and numerical solution of these systems will be addressed and numerical examples will be presented. Potential direction for future research and connections with experimental results will be discussed.

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MS35

Thermodynamic Modeling and Numerical Simulation of the Flow of Wormlike Micellar Solutions

In this talk, we present a new model for wormlike micellar solutions, a class of viscoelastic fluids. The dynamic aggregation/de-aggregation processes of the surfactant molecules were described using a nonequilibrium extension to the mass-action treatment of chemical reaction kinetics. The model has few parameters and satisfies the principles of nonequilibrium thermodynamics. Time-dependent simulations were performed on an inhomogeneous shear flow using a semi-implicit Chebyshev method.

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MS35

Boundary Feedback Control Designs for the Boussinesq Equations with Application to Control of Energy Efficient Building Systems

Theoretical and numerical results for feedback stabilization of the Boussinesq Equations with fnite dimensional boundary controllers are discussed. The problem is motivated by design and control of energy effiefficient building systems. In particular, new low energy concepts such as chilled beams and radiant heating lead to problems with Dirichlet, Neumann and Robin type boundary conditions. It is natural to consider control formulations that account for minimizing energy consumption and providing reasonable performance. We discuss a LQR type control problem for this system with Robin/Neumann boundary control inputs and apply the results to a 2D problem to illustrate the ideas and demonstrate the computational algorithms.

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MS35

Formulation and Simulation of the Force-Based Blended Quasicontinuum Method

The development of consistent and stable atomistic-to-continuum coupling models for multi-dimensional crystalline solids remains a challenge. For example, proving stability of the force-based quasicontinuum (QCF) model remains an open problem. In 1D and 2D, we show that by blending atomistic and Cauchy– Born continuum forces, one obtains positive-definite blended forcebased quasicontinuum (B-QCF) models. We establish sharp conditions on the required blending width, which is much narrower than the macroscopic regions.

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MS35

Finite-Temperature Dynamics of Matter-Wave Dark Solitons in Linear and Periodic Potentials

We study matter-wave dark solitons in atomic Bose-Einstein condensates at finite temperatures, under the effect of linear and periodic potentials. Our model, namely a dissipative Gross-Pitaevskii equation, is treated analytically by means of dark soliton perturbation theory, which results in a Newtonian equation of motion for the dark soliton center. For sufficiently small wavenumbers of the periodic potential and weak linear potentials, the results are found to be in good agreement with pertinent ones obtained via a Bogoliubov-de Gennes analysis and direct numerical simulations.

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MS36

Polynomial Systems in Receptor Pharmacology

Pharmacology studies interactions between biological processes and therapeutic agents. It is usually viewed as consisting of two subdisciplines: pharmacokinetics (what the body does to the drug) and pharmacodynamics (what the drug does to the body). Receptor pharmacology is a common foundation, which, at the beginning of the research pipeline, is concerned with "pharmacostatics", the in vitro equilibrium states of key biochemical interactions involving receptors. At the core of the applicable mathematical models are certain systems of polynomial equations. Established practices are to solve these systems in closed form at all cost (or give up). Sometimes the assumptions intended to justify such simplifications are dubious. Sometimes the simple, closed-form formulas are incapable of revealing experimentally observed features. As a result, candidate molecules can be assessed overoptimistically or discarded prematurely. This presentation will discuss efforts to develop methods to solve these polynomial systems systematically with a priori assurance of convergence, and a related success case of simulating and explaining an unforeseen experimental observation.

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MS36

Weather Normalization of Temperature Sensitive Peak Loads

Analyses of the available methodologies for weather normalizing temperature sensitive loads within a geographically and customer diverse service territory has been conducted. Multiple explanatory variables have been analyzed in conjunction with various extreme heat / thermal comfort models in order to create adaptive temperature sensitive correlation techniques for normalized distribution substation peak loads. A field study of extreme value analysis theories was also conducted to determine the best probabilistic approach for determining one-in-ten year temperatures for distribution substations using an ensemble of weather stations with limited historical information. Results from each study are provided to demonstrate the robustness of the proposed models, as well as limiting the volatility of weather normalized substation peak loads to increase long term forecast accuracy.

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MS36

A Mathematician's Apology

A reflection of thiry four years working in industry, by a mathematician with no initial inclination or notion to work outside academia. The presentation will discuss: common mathematical themes, the role of a theoretical mathemation as an engineering project team member, preparation for industry, keeping it interesting, challenging, rewarding, and fun.

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MS36

Systems Pharmacology: Current Applications of Mathematics in Pharmaceutical R&D

The cost of new marketed drugs continues to climb due to the time it takes to bring a drug candidate from discovery to approval and the rising costs of developing the drug. Recent data suggest the average cost for a drug approval is now between $400 million to $1 billion. One main reason for these soaring costs is the high attrition rate of drugs in Phase 2 clinical trials. The root cause of these failures is typically the drug's mechanism of action. Efforts have been underway in the industry to better understand drug mechanisms long before they reach Phase 2 trials. In fact, the area now known as systems pharmacology was created in large part to better understand drug mechanisms early in the discovery phase through clinical development. Systems pharmacology is the integration of numerous disciplines, including mathematics, engineering, physics, biology and chemistry, with the goal of building dynamical systems to model drug mechanisms via computer simulation and theoretical analysis. Methods that are commonplace in engineering and physics are now being implemented in drug discovery programs, such as mass-balance principles, dynamical systems analysis, optimization and inverse problems, and model-parameter sensitivity analysis. This presentation will showcase examples of these methods in a drug discovery setting within pharmaceutical R&D.

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MS37

Advances in Smoothed Particle Hydrodynamics

In this paper, we systematically explore the accuracy and stability of different methods for satisfying boundary conditions and capturing viscous diffusion in smoothed particle hydrodynamics (SPH). Smoothed particle hydrodynamics (SPH) is a Lagrangian method for compressible and incompressible flows. The state of fluid system is represented by a set of moving basis functions which interpolate the material properties. The mesh-free formulation of the method and its inherent stability make it popular for problems that have complex geometry or large deformations. Our research focuses mathematically on an accurate and efficient treatment for physical boundary conditions. Also, we analyze several smoothing kernels and diffusion schemes. We compare different techniques for non-slip, non-penetration conditions such as fixed fluid particles, ghost particles and boundary particle forces. We verify our results by comparing computations to exact solutions for 2D planar and circular, steady and unsteady Couette flows.

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MS37

A Numerical Study of the Accuracy of Divergence-Free Kernel Approximations

We present a numerical study of the accuracy of divergence-free radial basis function discretizations. When compared to standard interpolants, our results indicate that using a divergence-free basis improves accuracy of derivatives present in the divergence operator. Derivatives in other directions are often less accurate. In this talk we explore strategies for improving approximations in these directions and compare accuracy of methods based on radial kernels and multivariate polynomials.

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MS37

Kernel Quadrature and Meshless Galerkin Methods on $\mathbf{S^2}$

Recently, Fuslier, Hangelbroek, N., Ward and Wright have obtained accurate, stable quadrature formulas for $\mathbf{S^2}$ that use their newly developed robust bases for certain spaces of kernels. Such bases consist of Lagrange-like functions that are rapidly decaying spatially and have "small footprint' in the set of kernels. In this talk we discuss applying these quadrature formulas to study Galerkin methods for solving PDEs on $\mathbf{S^2}$.

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MS37

An RBF-FD Method for the Simulation of Reaction-Diffusion Equations on Stationary Platelets Within the Augmented Forcing Method

The Augmented Forcing Method (AFM) is a recently-developed numerical methodology for the simulation of PDEs on irregular domains. Our specific motivation is the modeling of the chemistry of platelet aggregation. This involves solving chemical diffusion equations in the blood around platelets with boundary conditions obtained from the solution of reaction-diffusion equations on the platelet surfaces. In this talk, we present a methodology for using Radial Basis Function (RBF)-Finite Differences to solve reaction-diffusion equations on platelet surfaces, RBF-based modifications to the AFM to eliminate some of its limitations, and results for coupled problems involving stationary platelets on irregular domains in two-dimensions.

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MS38

Near-Optimal Column-Based Matrix Reconstruction

We study the problem of constructing low-rank approximations to a matrix by using only a small subset of its columns. We present (deterministic and randomized) approximation algorithms with respect to both the spectral and the Frobenius norm. In terms of approximation bounds, our algorithms are optimal, up to small constant factors. The main tools we introduce to obtain our results are: (i) the use of fast approximate SVD-like decompositions, and (ii) two deterministic algorithms for selecting rows from matrices with orthonormal columns, building upon the sparse representation theorem for decompositions of the identity that appeared in [BSS09].

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MS38

Sketching Algorithms and the Skylark Project

Sketching methods could be summarized as follows: a sketch of a matrix A is its product SA with a sketching matrix S, where S is chosen so that SA behaves likes A, in the sense that for all vectors x, $||SAx||$ is about the same as $||Ax||$. From this *subspace embedding* property follows a number of applications where SA can be used in place of A, and yield provably good appropriate solutions. When S has a small number of rows, so does the sketch SA, and using SA in place of A results in fast approximation algorithms. I will briefly describe a few sketching matrices, a few applications, and an ongoing project, called "Skylark", to implement numerical linear algebra algorithms based on sketching, for large-scale data analysis.

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MS38

Accuracy of a Randomized Algorithm for Computing Leverage Scores

The leverage scores of an $m \times n$ matrix A ($m > n$) are the squared row norms of any matrix containing an orthonormal basis for the column space of A. Leverage scores give information about the importance of rows in regression problems and have also been used in the construction of sampling probabilities for low-rank matrix approximation. Drineas et al. (2011) have developed a randomized algorithm for approximating leverage scores that uses random projections. We present new bounds on the error produced by the algorithm that improve upon previous analysis and do not rely on the random projections being Johnson-Lindenstrauss transforms.

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MS38

Robust PCA for Massive Data

The problem of low-dimensional approximation in the presence of outliers is well studied in the statistics and applied mathematics communities. Unfortunately, all existing methods are either intractable or computationally intensive for modern "massive' data. We propose an innovative algorithm for robust PCA taking inspiration from recent developments in randomized numerical linear algebra. We illustrate the performance of our method on synthetic data as well as astronomical spectra from the Sloan Digital Sky Survey.

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MS39

Zeros of Entire Fourier Transforms, Lee-Yang Measures and the Riemann Hypothesis Via Orthogonal Polynomials

The following fundamental problem arose independently in two seemingly completely distinct areas as number theory and statistical mechanics. The principal question was formulated first by George Pólya in 1926 who was motivated by his efforts to settle the Riemann hypothesis. It states: under what additional conditions on the sufficiently smooth and rapidly decreasing kernel $K(t)$ its Fourier transform is an entire function which possesses only real zeros? Essentially the same question arose in Statistical Mechanics. A measure is said to have the Lee-Yang property if all zeros of its Fourier transform are real and the problem is to characterize those measure. It has been motivated by the celebrated Lee–Yang theorem, established in 1952, for which Lee and Yang were awarded the 1957 Nobel Prize in physics. The theorem states that if the partition functions of models with ferromagnetic interactions are considered as functions of an external field, then all zeros are purely imaginary. The original version of the result concerns the so-called Ising model. Further extensions and generalizations are due to R. Griffiths and B. Simon (1973), C. Newman (1974) and Lieb and Sokal (1981). We report a result which provides a characterization of the Lee–Yang measures and a solution of Pólya's problem too, in terms of the polynomials, orthogonal with respect to the measure.

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MS39

Asymptotics of Carleman Polynomials for Level Curves of the Inverse of a Shifted Zhukovsky Transformation

In this talk we study the asymptotic behavior of polynomials orthogonal over the interior of the analytic Jordan curve $L = \{z = w - 1 + (w - 1)^{-1},\ |w| = R\}$, for some $R > 2$. Surprisingly, this variation of the classical example of the ellipse turns out to be quite sophisticated. After properly normalizing the corresponding orthonormal polynomials p_n, $n = 0, 1, \ldots$, and on certain critical subregion of the orthogonality domain, a subsequence $\{p_{n_k}\}$ converges if and only if $\log_{\mu^4}(n_k)$ converges modulo 1 (μ being an important quantity associated to L).

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MS39

Generalized Hurwitz Matrices, Multiple Interlacing, and Forbidden Sectors of the Complex Plane

We examine polynomials whose generalized Hurwitz matrices are totally positive and establish that their zeros always avoid specific sectors of the complex plane. We also point out some intriguing connections with (branching) continued fractions and with zero interlacing.

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MS39

Equilibrium Measure and Phase Transitions in the Random Matrix Models

The large-scale behavior of many models in mathematics and physics, such as a unitary random matrix ensemble, the non-intersecting Brownian paths, or the asymptotics of orthogonal polynomials with respect to a varying weight, are described in terms of a measure solving an extremal problem from the logarithmic potential theory. This measure (the equilibrium measure in an external field) provides a crucial information: the associated functionals give us the leading terms of the asymptotics, and its support is typically the place where oscillations occur. In particular, the phase transitions in the random matrix models are associated to the change of the topology and connectivity of the support of the equilibrium measure under variations of the external field. In a rather broad class of problems the potential (or the external field) on the real line is given by a polynomial. Much has been written about the phase transitions for the polynomial potentials. In this talk we show that the main known (and a few unknown) facts can be derived in a unified fashion from two basic properties of the equilibrium measures. As an illustration, we discuss in more detail the case of the quartic external field, focusing on the possible transitions between different configurations of the limiting spectrum under the variation of the total mass of the measure.

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MS40

A Tale of Two Theorems

I will explain and draw connections between the following two classical theorems: (1) Classification of varieties of minimal degree by Del Pezzo and Bertini, (2) Hilbert's theorem on nonnegative polynomials and sums of squares. This will lead to a sharp generalization of Hilbert's result. (Joint work with Greg Smith and Mauricio Velasco).

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MS40

Truncated Moment Problems, Extensions, and Positivity

At present, several interrelated solutions to the multivariable truncated moment problem are known, based on flat extensions of positive moment matrices and positive extensions of Riesz functionals. In general, these are abstract solutions. We discuss several cases in which concrete solutions can be obtained, and some cases in which approximate representing measures can be produced based on limits of positive flat moment matrices.

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MS40

Inequalities on Polynomials in Matrix Variables

Matrix inequalities which occur in much of linear system theory often require that several polynomials in matrices are positive semidefinite. Our goal is to describe some theory under development for noncommutative polynomial inequalities. It parallels classical real algebraic geometry. The work described is joint with Igor Klep, Scott Mccullough and Chris Nelson.

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MS41

Mutliresolution Spectral Image Segmentation

Spectral image segmentation requires numerical solution of an eigenvalue problem for the corresponding graph Laplacian matrices of very large sizes. We demonstrate that our LOBPCG [2001 AV Knyazev Toward the optimal preconditioned eigensolver: Locally optimal block preconditioned conjugate gradient method. SIAM Journal Scientific Computing 23 (2), 517-541.] eigenvalue solver in the BLOEX-hypre software library [2007] AV Knyazev, ME Argentati, I Lashuk, EE Ovtchinnikov, Block locally optimal preconditioned eigenvalue xolvers (BLOPEX) in HYPRE and PETSc, SIAM Journal Scientific Computing 29 (5), 2224-2239.] can be used for efficient and high quality spectral image segmentation. We numerically analyze two alternative mutliresolution approaches.

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MS41

Fast and Robust PCA

Consider a dataset of vector-valued observations that consists of a modest number of noisy inliers, which are explained well by a low-dimensional subspace, along with a large number of outliers. We first review a convex optimization problem and its efficient implementation that can reliably fit a low-dimensional model to this type of data. We then modify this framework to obtain a procedure for robust truncated SVD. We demonstrate its partial theoretical support and experimental successes. This talk is based on four different joint works: 1) with Teng Zhang, 2) with Michael McCoy, Joel Tropp and Teng Zhang, 3) with Matthew Coudron, and 4) with Tyler Maunu

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MS41

On the Optimal Design of Cascaded Classifiers for Object Detection

Abstract not available at time of publication.

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MS41

Forgery Detection in Paintings

This work studies how machine learning and image analysis tools can be used to assist art experts in the authentication of unknown or doubtful origin. Previous work has shown that variation in image clarity in the experimental data sets was correlated with authenticity, and may have acted as a confounding factor, artificially improving the results. Therefore, a data set with ground truth and uniform acquisition conditions is provided to determine the extent of this factor's influence. While many previously successful methods turn out to be ineffective, supervised machine learning on features extracted from Hidden-Markov-Tree modeling of the paintings' wavelet coefficients demonstrates its potential to distinguish copies from originals in this data set. In order to further study and improve this approach, a larger data set is created under similar conditions. In addition, more careful analysis and experiments are conducted to provide new insights.

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MS42

Applications of Painlevé Functions to Nonlinear Wave Equations

It has recently been discovered that solutions of nonlinear wave equations in certain transition regions can be universally described for wide classes of initial conditions in terms of Painlevé functions. These functions play a role for nonlinear equations analagous to the role played by the classical special functions for linear equations. We will present our recent result with P. Miller establishing Painlevé-type asymptotics in solutions of the semiclassical sine-Gordon equation.

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MS42

Semi-Classical Orthogonal Polynomials and the Painlevé Equations

In this talk concerns the relationship between the Painlevé equations and orthogonal polynomials with respect to semi-classical weights. Orthogonal polynomials satisfy a three-term recurrence relation and for some semi-classical weights, the recurrence coefficients can be expressed in terms of Wronskians of special functions which arise in the description of classical solutions of Painlevé equations. Orthogonal polynomials with respect to a semi-classical Laguerre weight and semi-classical generalizations of Charlier

and Meixner polynomials will be discussed.

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MS42

Asymptotic Behavior of Rational Solutions to the Inhomogeneous Painlevé-II Equation

The inhomogeneous Painlevé-II equation with constant parameter α has a unique rational solution exactly when α is an integer. This talk concerns the asymptotic behavior of this rational solution in the limit of large $|\alpha|$. Using Riemann-Hilbert techniques, we prove the existence of a curvilinear triangle asymptotically confining the poles and zeros. In the interior of the triangle the rational solution is asymptotically described by elliptic functions. Near the three corners, however, the Hamiltonian of the tritronquée solution of the Painlevé-I equation describes the asymptotic behavior. This is joint work with R. Buckingham.

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MS42

Numerical Nonlinear Steepest Descent and Painlevé Transcendents

Abstract not available at time of publication.

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MS43

Bayesian Approaches to the Analysis of Computer Model Output

I discuss frameworks for incorporating large-scale computer model output into hierarchical Bayesian models. The framework allows analysts to treat uncertainties in model output by structuring them in the likelihood function or in the prior formulation or both. A hybrid approach is also discussed and illustrated. Examples presented involve geophysical problems.

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MS43

The Role of Additive and Multiplicative Noises in Filtering Complex Dynamical Systems

Covariance inflation is an ad-hoc treatment that is widely used in practical real-time data assimilation algorithms to mitigate covariance underestimation due to model errors, nonlinearity, or/and, in the context of ensemble filters, insufficient ensemble size. In this paper, we systematically derive an effective statistical inflation for filtering multi-scale dynamical systems with moderate scale gap, $\epsilon = O(10^{-1})$, to the case of no scale gap with $\epsilon = O(1)$, in the presence of model errors through reduced dynamics from rigorous stochastic subgrid-scale parametrizations. We will demonstrate that for linear problems, an effective covariance inflation is achieved by a systematically derived additive noise in the forecast model, producing superior filtering skill. For nonlinear problems, we will study an analytically solvable stochastic test model, mimicking turbulent signal in regimes ranging from a turbulent energy transfer range to a dissipative range to a laminar regime. In this context, we will show that multiplicative noise naturally arises in addition to additive noise in a reduced stochastic forecast model. Subsequently, we will show that a "statistical" inflation factor that involves mean correction in addition to covariance inflation is necessary to achieve accurate filtering in the presence of intermittent instability in both the turbulent energy transfer range and the dissipative range.

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MS43

A Spectral Based Approach to Conditional Simulation of Climate

A rising body of evidence suggests that a changing climate may not simply involve increasing temperatures, but changing variability across multiple spatial and temporal scales as well. We propose a method of quantifying changing dependence structure that involves estimating the ratio of two spectral densities of climate model output under various GHG emissions scenarios. This estimated change in the dependence structure is used to produce conditional simulations of climate variables under different GHG emissions scenarios.

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MS44

Moving Target ISAR Imaging

Abstract not available at time of publication.

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MS44

Mathematical Problems Associated with Imaging Moving Objects

An understanding of Fourier transform theory provides much of the mathematical background needed to understand some commonly used SAR processing methods. But some inadequately solved problems in SAR signal processing motivate the study of other mathematical ideas. For example, unknown target motions lead to geometric inverse problems. Also, problems in SAR signal analysis have mo-

tivated us to want better understanding of methods for solving variational problems, and numerical issues related to repeated interpolations.

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MS44

On SAR Imaging through the Earth's Ionosphere

Ionospheric distortions of spaceborne SAR images are due to mismatches between the actual radar signals subject to temporal dispersion and Faraday rotation, and their ungarbled form assumed by the signal processing algorithm. We propose to probe the terrain and the ionosphere on two carrier frequencies. Then, we analyze the two images and retrieve the plasma parameters responsible for mismatches. This allows us to correct the matched filter and reduce image distortions. Work supported by AFOSR.

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MS44

Feature Extraction and Classification of Ground Moving Targets from ISAR Image Sequences

This paper presents algorithms for target model learning and discrimination using ISAR image sequences collected during vehicle turns. We begin by detecting range-cross range bins associated with target scattering centers in each image frame and associate them across frames to estimate features. We present an assumed-model feature modeling method and a distribution-free method. The algorithms are tested using airborne radar data. The results show promising discrimination capability, in particular the distribution-free method using Henze-Penrose statistic.

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MS45

Fast Numerical Algorithms for Kalman Filters and Data Assimilation

A common feature amongst inverse problems is that the parameters we are interested in estimating are hard to measure directly, and a crucial component of inverse modeling is using sparse data to evaluate many model parameters. We will present fast algorithms for geostatistical approaches and Kalman filters, with a computational cost that scales linearly with the problem size. We illustrate with examples from CO2 monitoring and crosswell seismic tomography.

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MS45

A Dynamically Bi-Orthogonal Method for Time-Dependent Stochastic Partial Differential Equation

We develop a dynamically bi-orthogonal method to study time dependent stochastic partial differential equations. The main advantage of our approach is to construct the Karhunen-Loeve expansion of the stochastic solution on-the-fly without the need to form the covariance matrix. We propose an adaptive strategy to dynamically remove or add modes, and perform a detailed complexity analysis. Several numerical experiments including stochastically forced Navier-Stokes equations will be provided to demonstrate the effectiveness of the method.

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MS45

Data Free Inference in Computational Models

Model calibration is frequently done in a context where raw data is not available, relying instead on data summaries or other information. We present a computational procedure for Bayesian inference in this context, relying on maximum entropy arguments. The method provides a pooled parameter posterior based on many proposed data sets that are consistent with the given information. We illustrate the structure and performance of the method using a model chemical system.

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MS45

Effective Approximation of Stochastic Navier-Stokes Equation

A new class of high-order stochastic approximations based on Wick-Malliavin series expansions for Gaussian and Uniform distributions will be discussed. Applications of these approximations to solutions of randomly forced Navier-Stokes and Burgers equations will be considered.

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MS47

Branch Decomposition Techniques for Matroid Circuit Problems

We present a new algorithm to address the linear matroid cogirth problem which utilizes the branch decomposition. Addressing this problem can lead to significantly enhancing the design process of sensor networks. The solution to this problem provides the degree of redundancy of the corresponding sensor network, and allows for the evaluation of the quality of the network. We also provide computational results to validate efficacy of the algorithm.

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MS47

Euclidean Hub-and-spoke Networks

The hub-and-spoke distribution paradigm has been a fundamental principle in geographic network design for more than 40 years. One of the primary advantages that such networks possess is their ability to exploit economies of scale in transportation by aggregating network flows through common sources. In this paper, we consider the problem of designing an optimal hub-and-spoke network in continuous euclidean space: the spokes of the network are distributed uniformly over a service region, and our objective is to determine the optimal number of hub nodes and their locations. We consider five different backbone network topologies for connecting the hub nodes, namely the Steiner and minimum spanning trees, a travelling salesman tour, a star network, and a complete graph. We describe the asymptotically optimal (or near-optimal) configurations that minimize the total network costs as the demand in the region becomes large and give an approximation algorithm that solves our problem on a convex planar region for any values of the relevant input parameters.

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MS47

On the 4/3 Conjecture for the Symmetric TSP

The Traveling Salesman Problem (TSP) arises in fields ranging from route planning, to manufacturing, to genetics. Better solutions to this problem will reduce operating costs across a diverse spectrum of industries. This talk examines an approach to proving a tight bound on the integrality gap of the Held-Karp relaxation of the integer program model of the TSP. The approach is constructive, and can be used to motivate an improved approximation heuristic for the TSP.

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MS47

Finding all Minimal k-Cores in Graphs for Modeling k-Assemblies

We present a recursive algorithm to find all minimal k-cores of a given undirected graph, which belongs to the class of NP-complete problems. The proposed method is a modification of the Bron and Kerbosch algorithm for finding all cliques of an undirected graph. The minimal k-core problem has applications in the area of neuroscience. For

example, in the study of associative memory, a cell assembly is a group of neurons that are strongly connected and represent a "concept" of our knowledge. This group is wired in a specific manner such that only a fraction of its neurons will excite the entire assembly. Recent studies have linked the concept of a particular type of cell assembly called k-assembly to the closure of a minimal k-core. Therefore, the proposed method puts us a step closer to test its mathematical definition.

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MS48

Application of Population Dynamics on Heterotypic Cell Aggregation in Tumor Metastasis

This work studied the process of polymorphonuclear neutrophils tethering to the vascular endothelial cells, and subsequential tumor cell emboliformation in a shear flow, an important process of tumor cell extravasation during metastasis. The focus lies in modeling of the process and application of Bayesian framework to the related parameter identification problems. Quantitative agreement was found between numerical predictions and in vitro experiments. The effects of factors, including: intrinsic binding molecule properties, near-wall heterotypic cell concentrations, and cell deformations on the coagulation process, were discussed. Sensitivity analysis has been done, and we concluded that the reaction coefficient along with the critical bond number on the aggregation process should be recommended as the most critical variables.

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MS48

Uncertainty Quantification for Large-Scale Bayesian Inverse Problems with Application to Ice Sheet Models

We address the problem of quantifying uncertainty in the solution of inverse problems governed by Stokes models of ice sheet flows within the framework of Bayesian inference. The posterior probability density is explored using a stochastic Newton MCMC sampling method that employs local Gaussian approximations based on gradients and Hessians (of the log posterior) as proposal densities. The method is applied to quantify uncertainties in the inference of basal boundary conditions for ice sheet models.

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MS48

Dynamic Model of DNA Structure and Function

Our research has focused on developing a dynamic statistical mechanical model for predicting the mechanical behavior of DNA in an evolving biological environment. We model events like transcription and protein binding. Among the measures calculated are the time-series probability distribution, time-dependent energy of opening and probability of opening for each base pair of the DNA chain. Our dynamic model thus enables a better understanding of mechanisms in the cell and function of DNA in vivo.

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MS48

Transmission Dynamics of Escherichia Coli O157:H7 in a Cattle Population

Escherichia coli O157:H7 is an important foodborne pathogen with a natural reservoir in the cattle population. To understand the spread and persistence of E. coli O157:H7 infection in cattle so that better infection control strategies can be designed, I proposed a stochastic model for E. coli O157:H7 transmission in cattle. In this work, the Kolmogorov equations that determine the probability distribution and the expectation of the first passage time were rigorously derived in a general setting. As an application of the theoretical results to E. coli O157:H7 infection, I will talk about the extinction and outbreak of infection by solving the Kolmogorov equations associated with statistics of the time to extinction and outbreak. The results provided insight into E. coli O157:H7 transmission and apparent extinction, and suggested ways for controlling the spread of infection in a cattle herd. Specifically, this study highlighted the importance of ambient temperature and sanitation, especially during summer.

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MS50

Reduced Complexity Models for Stochastic Systems

We consider nonlinear advection-reaction equations (AREs) with uncertain (random) velocity and reaction parameters. For a class of reactions we derive a deterministic equation that governs the evolution of cumulative distribution function (CDF) of a solution of the underlying ARE. This differential equation is subject to uniquely defined boundary and initial conditions, and can be solved with classical techniques once a closure is introduced. Here we analyze the accuracy and robustness of the large-eddy-diffusivity closure.

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MS50

Coarse-Grid Sampling Interpolatory Methods for Approximating Correlated Random Fields

Random fields, corresponding to the parameters of a PDE, can be approximated using grid-based discretizations of their covariance functions followed by factorization of the resulting covariance matrix. In this paper, we consider efficiency gains obtained by using low-rank approximations based on constructing a coarse grid covariance matrix, followed by factorization and interpolation from the coarse onto the fine grid. The result is coarser sampling and smaller decomposition problems than that for full-rank approximations.

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MS50

A Multilevel Stochastic Collocation Algorithm for Optimization of PDEs with Uncertain Coefficients

Gradient-based algorithms for optimization of PDEs with uncertain coefficients are often computationally intractable. We investigate an adaptive multilevel stochastic collocation framework for the solution of such optimization problems. Our framework is based on the trust-region algorithm for which we prove global convergence under weak assumptions on gradient inexactness. In the stochastic collocation framework, the state and adjoint equations are solved concurrently. Numerical results for the adaptive solution of these optimization problems are presented.

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MS50

High Dimensional Interpolation for Multiphysics Models

Cycle-to-cycle variations in power output of combustion engines is a major obstacle to increasing fuel efficiency, however, the causes of such variations are not fully understood. We take a multiphysics computationally expensive engine model that combines turbulence, thermodynamics and chemistry. Using high dimensional interpolation techniques, we create a cheap model approximation that is used to study the correlation between the various parameters of engine operations and the cycle-to-cycle power variations.

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MS51

Randomized Preconditioning

Abstract not available at time of publication.

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MS51

Randomized Solvers for Regession Problems

We will review recent development of randomized subspace embedding algorithms and emphasize their applications to large-scale strongly over-determined ℓ_p regression and quantile regression problems. For ℓ_2, we show that a $(1+\epsilon)$-approximate solution to the ℓ_2 regression problem specified by a matrix $A \in R^{n\times d}$ $(n \gg d)$ and a vector $b \in R^n$ can be computed in $\mathcal{O}(\mathrm{nnz(A)} + \mathrm{d}^3 \log(\mathrm{d}/\epsilon)/\epsilon^2)$ time; for ℓ_p, via a subspace-preserving sampling procedure, we show that a $(1+\epsilon)$-approximate solution to the ℓ_p regression problem $\min_{x\in R^d} \|Ax-b\|_p$ can be computed in $\mathcal{O}(\mathrm{nnz(A)} \cdot \log \mathrm{n} + \mathrm{poly(d)} \log(1/\epsilon)/\epsilon^2)$ time; and similar results apply to quantile regression problems.

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MS51

Subsampling, Regularization and Leverage Scores

Abstract not available at time of publication.

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MS51

Sensitivity of Leverage Score Estimation

Leverage scores were introduced in 1978 by Hoaglin and Welsch for outlier detection in statistical regression analysis. Starting about ten years ago, Mahoney et al. pioneered the use of leverage scores for importance sampling in randomized algorithms for matrix computations. We present perturbation bounds for leverage scores in terms of principal angles between subspaces. We also consider the context of machine learning applications, where perturbations are small only when compared to regularization terms, and present perturbation bounds for large leverage scores. This is joint work with Ilse Ipsen.

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MS52

Isoperimetric Inequalities for a Wedge-like Membrane

: For a wedge-like membrane, Payne and Weinberger proved in 1960 an isoperimetric inequality for the fundamental eigenvalue which in some cases improves the classical isoperimetric inequality of Faber-Krahn. In this work, we introduce "relative torsional rigidity' for this type of membrane and prove new isoperimetric inequalities in the spirit of Saint-Venant, Pólya-Szegő, Payne, Payne-Rayner, Chiti, and Talenti, which link the eigenvalue problem with the boundary value problem in a fundamental way. (Joint work with A. Hasnaoui, University of Tunis, El Manar)

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MS52

Principal Eigenvalue Minimization for An Elliptic Problem with Indefinite Weight and Robin Boundary Conditions

Abstract not available at time of publication.

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MS52

Applications of Laplace-Beltrami Spectrum Via Conformal Deformation

The spectrum of Laplace-Beltrami (LB) operator plays an important role in surface analysis and has been made successful applications in many fileds such as computer graphics and medical image analysis. This talk will discuss our recent work about variation of LB spectrum via conformal deformation and its applications in shape analysis.

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MS52

Extremal Eigenvalues of the Laplace-Beltrami Operator

Let (M, g) be a 2-dimensional, compact, connected Riemannian manifold and denote by $\lambda_k(g)$ the k-th eigenvalue of the Laplace-Beltrami operator, Δ_g. In this talk, we fix M and consider the dependence of the mapping $g \mapsto \lambda_k(g)$. In particular, we propose a computational method for solving the eigenvalue optimization problem of maximizing $\lambda_k(g)$ over a conformal class $[g]$ of fixed volume, $\mathrm{vol(M,g)} = 1$.

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MS53

On Stable Discretizations for Non-Newtonian Flow Model by DG and Nonconforming FEMs

We present a class of stable discretization schemes for solving the 3-dimensional non-Newtonian flow model by Discontinuous Galerkin and nonconforming FEMs. In this formulation, unlike the case the conforming finite elements are used, the velocity fields approximated by low order piecewise polynomials can be shown to satisfy the strong divergence-free condition, still achieving the stability in terms of the energy norms. Numerical Experiments will be presented to demonstrate the robustness of the algorithm. This is the joint work with Q. Hong and J. Xu

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MS53

Regularity and Multigrid Analysis for Laplace-Type Axisymmetric Equations

We discuss new high-order full regularity estimates in weighted Sobolev spaces for a class of 2D equations reduced from 3D Poisson's equation on axisymmetric domains. Based on these estimates, we develop high-order finite element methods that approximate singular solutions of these equations in the optimal rate. Then, we show our analysis on the condition number of the system from the finite element discretization. This, together with our results on the approximation properties of the finite element solution and the smoothing properties of the smoother in the multigrid V-cycle algorithm, will lead to the uniform convergence of the multigrid method for the axisymmetric equations.

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MS53

Uncertainty Quantification for Elliptic Problems on Polyhedral Domains

Let $D \subset R^d$, $d = 2, 3$, be a bounded domain with piecewise smooth boundary ∂D and let U be an open subset of a Banach space Y. We consider a parametric family P_y of uniformly strongly elliptic, second order partial differential operators P_y on D in divergence form, where the parameter y ranges in the parameter domain U so that, for a given set of data f_y, the solution u and the coefficients of the parametric boundary value problem $P_y u = f_y$ are functions of $(x, y) \in D \times U$. Under suitable regularity assumptions on these coefficients and on the source term f, we establish a regularity result for the solution $u : D \times U \to \mathbf{R}$ of the parametric, elliptic boundary value problem $P_y u(x, y) = f_y(x) = f(x, y)$, $x \in D$, $y \in U$, with mixed Dirichlet-Neumann boundary conditions. This will help in developing optimal finite element methods for these equations. This is joint work with Christoph Schwab, ETH Zurich.

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MS53

Convergence of Goal-Oriented Adaptive Finite Element Methods for Nonlinear Problems

In goal-oriented methods we are concerned with approximating a given quantity of interest, a function of the weak solution to the PDE. The adaptive algorithm is driven by estimating the error in both the primal and a dual problem at each iteration. We will discuss the formation of appropriate dual problems for nonlinear PDE and how they may be used to attain convergence and in some cases contraction results for the adaptive method. We will compare estimates for bounding the error in the goal function and how these estimates may be used in a convergence framework. Finally, we will look at some numerical experiments. This is joint work with Michael Holst and Yunrong Zhu.

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MS54

Coarse-Graining Agent-Based Models of Collective Motion

Abstract not available at time of publication.

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MS54

Spin Models for Suspensions of Swimming Microorganisms

One of the striking results from numerical simulations of force-dipole swimmer suspension models is the proclivity of swimmers with a positive force dipole to create structured patterns and those with negative force dipole to prefer isotropy. We investigate some simple spin models which abstract some features of these swimmer models, where we can develop, through a system of associated stochastic PDE's, much more precise, and we hope instructive, results concerning correlation structure and pattern formation.

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MS54

An Optimal Transport Approach to Statistical Inference Across Multiple Scales

In many statistical inference applications, ranging from "sloppy' models in systems biology to flow in porous media, data ultimately depend on a low-dimensional set of coarse-scale quantities. In this context, we can exploit conditional independence of scales, identified through multiscale models, to efficiently sample the Bayesian posterior. We describe a new inference methodology, based on inversion of a triangular optimal transport map, to condition the fine scale on coarse observables. The map is constructed as the continuous limit of a discrete transport map, allowing flexible application to a wide range of physical phenomena.

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MS54

Simulating Multiscale Particle-Based Models of Bacterial Chemotaxis with Asymptotic Variance Reduction

We discuss variance reduced simulations for an individual-based model of chemotaxis of bacteria with internal dynamics. The variance reduction is achieved via a coupling of this model with a simpler process in which the internal dynamics has been replaced by a direct gradient sensing of the chemoattractants concentrations. We first compute

a deterministic solution of the kinetic density description of the direct gradient sensing model; the deviations due to the presence of internal dynamics are then evaluated via the coupled individual-based simulations. We show that the resulting variance reduction is asymptotic, in the sense that, in the diffusive asymptotics, the difference between the two processes has a variance which vanishes according to the small parameter.

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MS55

Spatial Models of Biodiversity

Most biodiversity models are spatially implicit, for reasons of mathematical and computational tractability. Spatially explicit models, however, are required to provide more realistic descriptions of biodiversity patterns and to interface with spatially explicit data, which are becoming increasingly available. I will present two research projects on this topic: The first looks at spatially explicit models of species abundance distributions and the second looks at how species-area curves are affected by different landscape fragmentation patterns.

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MS55

Optimal Control of Spatial Models of Populations

The tool of optimal control is used to investigate issues of resource allocation and movement along a resource gradient for population models. The models are formulated as diffusive partial differential equations with nonlinear growth terms. Some models include advection terms for directed movement.

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MS55

Integrative Evaluation of Diverse Conservation Strategies for a Rare Shrub Species under Global Change

We link urban growth, species distribution, fire risk and population simulation models to investigate the impact of urban development, climate change and altered fire regime on the spatial distribution and persistence of a rare fire-sensitive shrub endemic to southern California, *Ceanothus verrucosus*. The modeling framework is used to rank spatially-explicit management actions: land conservation and a range of translocation scenarios. Results show that spatial conservation actions are only beneficial with appropriate temporal management of fire.

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MS55

Spatial Features of Density Dependence and Weather Extremes in Population Models

The spatial scale and spatial coherence of processes relevant for population dynamics, population persistence, and life histories has yet to be elucidated for many mobile organisms. Using fish populations as a model system, I show how the definition of the correct spatial scale for density-dependent processes and of spatial coherence of weather extremes increases the predictive power of models of evolution of life histories and population viability.

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MS56

Coarse-graining of Time and Space for Materials with Defects

Crack propagation, defect nucleation and movement, and plastic deformation are usually characterized by rare events where the system oscillates in an energy well and only rarely moves to a new state. The defects interact with boundaries and each other through long range elastic effects. Direct molecular dynamics cannot thus reach the time and space scales necessary for meaningful scientific and technological information. Thus, coarse-graining of the time dynamics to focus only on the state-to-state dynamics is needed concurrently with coarse-graining in space.

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MS56

Towards Rare Events Statistics in Molecular Dynamics

Rare event simulation and estimation for systems in equilibrium are among the most challenging topics in molecular dynamics. As was shown by Jarzynski and others, nonequilibrium forcing can theoretically be used to obtain equilibrium free energy differences. The advantage seems to be that the external force can speed up the sampling of the rare events by biasing the equilibrium distribution towards a distribution under which the rare events is no longer rare. Yet algorithmic methods based on Jarzynski's and related results often fail to be efficient because they are based on sampling in path space. We present a new method that replaces the path sampling problem by an optimal control. We show how to solve the related optimization problem in an efficient way by using an iterative strategy. This approach results in a zero variance estimator for committor functions, transition rates, or the statistics of first passage times.

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MS56

Importance Sampling in the Neighborhood of a Stable Equilibrium Point

We discuss importance sampling schemes for the estimation of finite time exit probabilities of small noise diffusion processes that involve escape from an asymptotically stable equilibrium. We build importance sampling schemes with provably good performance both pre-asymptotically, i.e., for fixed size of the noise, and asymptotically, i.e., as the size of the noise goes to zero, and that do not degrade as the time horizon gets large. Simulation studies demonstrate the theoretical results.

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MS56

Using Coarse Grained Models to Speed Convergence to the Minimum Energy Pathway

The minimum energy pathway (MEP) is the most likely transition pathway between reactant and product states in a chemical reaction at low temperature and provides a convenient, one dimensional, description of the event. For large complex systems interrogation of the reaction mechanism by straightforward simulation is often impossible due to the presence of a vast range of time scales. For this reason, efficient techniques that focus on discovery of the MEP are important. Unfortunately in large complex systems discovery of the MEP can itself be prohibitively expensive. In this work we develop a technique for discovery of the MEP (and other pathwise descriptions of a reaction) that uses cheap, coarse grained models to accelerate convergence. In most practical settings the reaction pathway corresponding to the coarse grained model does not accurately describe the reaction of interest. Nevertheless, by carefully arranging the calculation, the coarse grained system can be used to accelerate convergence to the MEP of a more expensive, more accurate, model. We demonstrate the effectiveness of this approach on several test problems.

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MS56

Metastability and Interacting Particle Systems

Metastablitiy of interacting particle systems can be studied based on large deviations for the sample path of the dynamics, in the spirit of Fredlin-Wentzell theory. We establish a large deviation principle for a general class of finite state mean field interacting particle systems. One highlight of our proof is it applies to the models that allows simultaneous jumps of particles, which is novel in the literature of LDPs for weakly interacting processes. With addition of some mild conditions, we also obtain a locally uniform LDP. Based on joint work with Paul Dupuis and Kavita Ramanan.

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MS57

SAR Imaging Considerations for Multi-Baseline Interferometry and Tomography

Synthetic aperture radar (SAR) interferometry and tomography use the complex phase information as well as the magnitude information from multiples vantages to extract vertical information. In order to obtain valid information of maximal quality necessitates some specialized processing schemes to preserve phase and maximize correlation. Moreover, adaptations are needed to support low frequency radars. This talk will cover some of the SAR signal processing considerations for these applications.

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MS57

Considerations in the Development of Passive Mul-

timode Radar

Passive multimode radar attempts to identify noncooperative transmissions and exploit them in a multistatic configuration to enhance target detection, location, and identification. This talk discusses passive multimode radar system implementation issues, modeling and simulation, and signal processing.

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MS57

Motion Estimation in Synthetic Aperture Radar

Abstract not available at time of publication.

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MS57

Interrupted SAR Persistent Surveillance Via Joint Sparse Reconstruction of Multi-Pass Data

We apply sparse signal recovery techniques for synthetic aperture radar (SAR) image formation from interrupted phase history data, with application to persistent surveillance SAR imaging. We extrapolate the missing samples by jointly processing multipass data using a sparse recovery technique with a group support constraint. We evaluate change detection performance using images from the Gotcha SAR and we find that joint processing results in coherent change detection gains regardless of interrupt pattern.

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MS58

Designing Uncertainty: Sensitivity Analysis for Systems with Spatially Distributed Variability

Engineers typically strive to minimize the amount of uncertainty in the systems they design. However, reducing uncertainty is typically associated with some cost. For example, tightening manufacturing tolerances incurs higher manufacturing costs. The cost associated with reducing uncertainty often competes with the benefits of improving performance, implying that there may be some optimal balance between the level of uncertainty and the performance of the system. We present an approach for computing the sensitivity of the statistics of performance to the level of uncertainty, and apply this approach to analyze and optimize problems with spatially distributed uncertainties.

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MS58

Predicting Energy Savings Due to Building Retrofit

Building energy performance is significantly affected by uncertainties in its parameters (e.g. equipment efficiencies) and by a number of uncertain processes (e.g. occupancy patterns). Building retrofits often fail to deliver expected energy savings because uncertainties are typically neglected during the design. We present methodology for uncertainty analysis for buildings that helps designers mitigate uncertainty and estimate correct energy performance bounds. The approach utilizes a number of different uncertainty analysis techniques.

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MS58

A Traveling Salesman Learns Bayesian Networks

Structure learning of Bayesian networks is an important problem that arises in numerous machine learning and uncertainty quantification applications. In this work, we present a novel approach for learning the structure of Bayesian networks using the solution of an appropriately constructed traveling salesman problem. In our approach, one computes an optimal ordering (partially ordered set) of random variables using methods for the traveling salesman problem. This ordering significantly reduces the search space for the subsequent greedy optimization that computes the final structure of the Bayesian network. We demonstrate our approach of learning Bayesian networks on real world census and weather datasets. In both cases, we demonstrate that the approach very accurately captures dependencies between random variables. We check the accuracy of the predictions based on independent studies in both application domains.

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MS58

An Adaptive Wavelet Stochastic Collocation Method for Irregular Solutions of PDEs with Random Inout Data

Accurate predictive simulations of complex real world applications require numerical approximations to first, oppose the *curse of dimensionality* and second, converge

quickly in the presence of steep gradients, sharp transitions, bifurcations or finite discontinuities in high-dimensional parameter spaces. In this talk we present a novel multi-dimensional multi-resolution adaptive (MdMrA) sparse grid stochastic collocation method, that utilizes hierarchical multi-scale piecewise Riesz basis functions constructed from interpolating wavelets. The basis for our non-intrusive method forms a stable multiscale splitting and thus, optimal adaptation is achieved. Error estimates and numerical examples will used to compare the efficiency of the method with several other techniques.

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MS60

Using Fast-slow Dynamical Systems Theory to Understand how Coevolution Shapes the Population Dynamics of Predator-prey Systems

Coevolution between predators and prey can potentially alter the population dynamics of predator-prey systems. Here, I use fast-slow dynamical systems theory to explore those effects. One prediction is that coevolution can effectively reverse the cycle orientation of predator-prey systems, yielding clockwise cycles in the phase plane. I compare this prediction to three experimental data sets and discuss new questions in dynamical systems that arise from fast-slow eco-coevolutionary models.

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MS60

Bifurcations, Infectious Disease Ecology and The Art of Approximation: Linking Biological Mechanisms with Dynamics

I'll discuss the dynamics of a consumer-resource (predator–prey) model, with infectious disease among consumers, in two parts: First I'll describe how resource-dependent epidemiological processes observed in natural systems can impact these three-species dynamics. Second, I'll discuss an approximation method that exploits the presence of multiple time scales in this system to describe how certain biological assumptions yield a Bautin (Generalized Hopf) bifurcation. This approximation provides useful biological insight, and raises new mathematical questions.

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MS60

Species Abundance Distributions in Ecological Communities with Niche and Neutral Dynamics

Whether and how dynamic processes underlying population growth influence species abundance distributions (SADs) is not yet well understood. We investigate the differences between SADs resulting from a stochastic competition model with neutral dynamics (based only on stochastic demographics), and with competition based on trait differences that gives rise to niches. We consider how the differences in SADs vary with factors such as number of niches, and how detectable we expect these differences to be in abundance data.

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MS60

Top-Down Bottom-Up Effects In The Chesapeake Bay Fisheries Ecosystem Model

In this talk, I will discuss both prey control (bottom-up control) and predator control (top-down control) mechanisms in a Chesapeake Bay ecosystem model. Through analyzing different scenarios of harvest and predation rates of the Atlantic menhaden, I will discuss evidence of bottom-up and top-down effects, with a particular interest in striped bass and phytoplankton biomass. The impacts of phytoplankton and zooplankton abundance on the dynamics of species in higher trophic levels will also be discussed.

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MS61

Numerical Construction of Green's Functions for High Dimensional Elliptic Problems with Variable Coefficients

We describe an algorithm for approximating the Green's function for elliptic problems with variable coefficients in arbitrary dimension d. The basis for our approach is the separated representation, which appears as a way of approximating functions of many variables by sum of products of univariate functions. As a corollary to this work, we describe a randomized algorithm for maintaining low separation rank of the functions used in the construction of the Green's function.

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MS61

A Partition of Unity Method with Penalty for Fourth Order Problems

The partition of unity method provides an easy way to construct smooth approximation spaces. One can use these approximation spaces in a Galerkin method, but special treatment is needed to enforce the Dirichlet boundary conditions. In this talk, we discuss a way to use the partition of unity method for fourth order problems with Dirichlet boundary conditions using Nitche's method. Details on the method, error estimates, and numerical examples will be presented.

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MS61

A Direct Solver for Variable Coefficient Elliptic PDEs

The talk describes a highly accurate technique for solving elliptic PDEs with variable coefficients and smooth solutions. The domain is tessellated into squares, and the differential operator is discretized via high order (p=10 or 20) spectral differentiation on each square. A hierarchical direct solver is used to solve the resulting discrete system. The method is very efficient; e.g., a Helmholtz problem on a domain of size 200x200 wavelengths is solved to ten digits of accuracy in ten minutes on a standard laptop (using 6M degrees of freedom).

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MS61

A Fast Algorithm for Spherical Grid Rotations and its Application to Singular Quadrature

We present a fast and accurate algorithm for evaluating singular integral operators on smooth surfaces that are globally parametrized by spherical coordinates. Problems of this type arise, for example, in simulating Stokes flows with particulate suspensions and in multi-particle scattering calculations. For smooth surfaces, spherical harmonic expansions are commonly used for geometry representation and the evaluation of the singular integrals is carried out with a spectrally accurate quadrature rule on a set of rotated spherical grids. We propose a new algorithm that interpolates function values on the rotated spherical grids via hybrid nonuniform FFTs. The algorithm is nearly optimal in computational complexity and reduces the cost of applying the quadrature rule from $\mathcal{O}(\surd^{\triangledown})$ to $\mathcal{O}(\surd^{\triangle} \log \surd)$ for a spherical harmonic expansion of degree p.

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MS62

Ramanujan and Symbolic Computation

This talk will be devoted to efforts using symbolic computation (MACSYMA) to place Ramanujan's fifth and seventh order mock theta functions in a coherent context. Among other things, this project has produced several new and unexpected identities related to derivatives of false theta functions.

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MS62

Creative Telescoping for Rational Functions using the Griffiths-Dwork Method

Creative telescoping algorithms compute linear differential equations with polynomial coefficients satisfied by multiple integrals depending on a parameter. We describe an algorithmic version of the GriffithsDwork method for the creative telescoping of rational functions. This leads to bounds on the order and on the coefficients degree of the differential equation, and to the first complexity result which is simply exponential in the number of variables. One of the important features of the algorithm is that it does not need to compute certificates.

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MS62

Recent Results for the Lambert W Function and its Relatives

We show that many functions containing the Lambert W function are Stieltjes functions. We discuss some of the consequences of this result, including some interesting definite integrals, series, and rational approximations. I think just add a sentence. We also discuss the convergence in the complex plane of series expansions for W.

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MS63

Performance Breakdown of Stochastic Simulation Algorithms

We study the performance of stochastic simulation algorithms for the propagation of epistemic uncertainty in nonlinear parabolic and elliptic models. For the estimation of first and second order moments, the loss of regularity of state variables in probability space with increasing variance, together with dimensionality limitations, affect negatively the performance of methods based in generalized Polynomial Chaos decompositions. Monte Carlo methods and their variants are shown to perform more robustly in application scenarios.

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MS63

Exploiting the Interpolating Property of Sparse Grids

It is common for a quantity of interest Q to be defined as an integral, expressed in terms of some state variable u depending on parameters λ. Estimating Q by a sparse grid requires evaluating the integrand at numerous settings for λ, and solving a nonlinear system for $u(\lambda)$. We investigate cases in which intermediate information produced by the sparse grid evaluation can be exploited to construct good starting values for the nonlinear state iteration.

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MS63

Numerical Methods for Stochastic Quasi-Geostrophic Equations

With the continuous increase in computational power, complex mathematical models are becoming more and more popular in the numerical simulation of oceanic and atmospheric flows. For some geophysical flows in which computational efficiency is of paramount importance, however, simplified mathematical models are central. For example, in climate modeling the Quasi-Geostrophic Equations (QGE), are commonly used in the numerical simulation of large scale wind-driven ocean circulations. Due to the requisite of long time integration in climate modeling, even for the simplified model, fast and accurate numerical algorithms are still desired. In this talk, we will pursue this direction and discuss efficient numerical approaches for QGE when uncertainty effects such as the random wind forcing are considered.

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MS63

A Hyper-Spherical Sparse Grid Approach for High-Dimensional Discontinuity Detection

High-dimensional discontinuity detection is important in UQ area, but conventional adaptive sparse-grid interpolation leads to dense refinement around discontinuities. We propose a novel method for identifying jump discontinuities in by incorporating a hyper-spherical coordinate system (HSCS) into the sparse-grid approximation framework. The basic idea is to transform the Cartesian coordinate system to an N-dimensional HSCS. Then a sparse-grid approximation is constructed in the N-1 dimensional subspace where the discontinuity locations are estimated using Newton method.

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MS64

A Multiscale Model of Fibrinolysis: from Single Molecules to Full 3-D Clots

Fibrinolysis, the enzymatic degradation of the fibrin mesh that stabilizes blood clots, is initiated through a reaction involving tissue-type plasminogen activator (tPA). tPA is used clinically to degrade blood clots, but bleeding complications often arise post-treatment. We develop a 3-dimensional stochastic multiscale model of fibrinolysis to investigate other possible treatments. The microscale model contains detailed biochemistry and represents a single fiber cross section. Data from the microscale model are used in a macroscale model of the full fibrin clot, where we explore various treatment options.

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MS64

A Model of Particle Transport Through a Periodic Array of Beating Cilia

In this talk, I will introduce a regularization method that gives a smooth formulation for the fundamental solution to Stokes flow driven by an infinite, triply-periodic array of point forces. With this formulation, the velocity at any spatial location may be calculated, including at and very near the point forces; these locations typically lead to numerical difficulties due to the singularity within the Stokeslet when using other methods. For computational efficiency, the current method is built upon previous methods in which the periodic Stokeslet is split into two rapidly decaying sums, one in physical space and one in reciprocal, or Fourier, space. I will show a few validation studies and then discuss a recent extension of the method to doubly-periodic flow. Finally, using the extended method, simulations of doubly-periodic arrays of beating cilia will be presented.

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MS64

Sperm Interactions: Biochemistry and Hydrodynamic Signals

Sperm have been observed to form sperm trains and self organize into vortices. What is the relative role of biochemistry and hydrodynamics in these interactions? In this talk, we will present recent computational results on attraction, synchronization, and the formation of sperm trains using the method of regularized Stokeslets. The coupling of biochemistry will be through the flagellar waveform and the role of these interactions in chemotaxis towards the egg will be discussed.

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MS64

Multiphase Models and Simulations for Bacterial Biofilm Accounting for Cell Motility

Biofilms are complex biological organisms ubiquitous almost everywhere in our daily life. Modeling and understanding the intricate biological, fluid mechanical, chemical-mechanical transduction of chemical signal and mechanical forces is a daunting task across multiple disciplines. In this presentation, we will present a systematic approach tooted in kinetic theory for complex fluids and expanded to include various biological and chemical mechanistic models to investigate how the biofilm flows in various geometry and boundary conditions. Hopefully, this will shed light on how to treat biofilm infections in medical settings or take advantage of the biofilm's barrier properties in their beneficial applications. Models and 3-D numerical simulations will be discussed in a few selected applications.

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MS65

Modeling, Shape Analysis and Computation of the Equilibrium Pore Shape near a PEM-PEM Intersection

In this work we investigate the equilibrium shape of an interface that represents the boundary of a pore channel embedded in an elastomer. The model consists of a system of PDEs, comprising a linear elasticity equation for displacements within the elastomer and a nonlinear Poisson equation for the electric potential within the channel (filled with protons and water). To determine the equilibrium interface, a variational approach is employed. We analyze: i) the existence and uniqueness of the electrical potential, ii) the shape derivatives of state variables and iii) the shape differentiability of the corresponding energy and the corresponding Euler-Lagrange equation. The latter leads to a modified Young-Laplace equation on the interface. This modified equation is compared with the classical Young-Laplace equation by computing several equilibrium shapes, involving a fixed point algorithm.

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MS65

On Embedded Eigenvalues of Non-Homogeneous Operators

In oscillatory systems extended in one dimension and containing a localized defect, embedded eigenvalues are made possible by symmetry, which allows a decoupling of propagating and evanescent motions. The corresponding eigenfunctions (bound states) have infinite support and decay exponentially. In systems without obvious symmetry or that are extended in multiple directions, such bound states are rare, and the obstructions are of algebraic nature. We examine special systems that do admit exponentially decaying bound states at embedded eigenvalues and discuss how asymmetry affects the resonant excitation of a bound state by radiation under small perturbations.

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MS66

Variable-Degree HDG Method for Convection-Diffusion Equations on Meshes with Hanging Nodes

The discontinuous Galerkin (DG) method is known to handle nonconforming meshes easily. But the presence of hanging nodes degrades its order of accuracy. This also holds for the hybridizable DG methods, more accurate than all classic DGM. We provide the first, rigorous a priori error analysis that shows the superconvergence properties of the HDG methods remain unaffected by the presence of hanging nodes for certain family of unstructured meshes. We also discuss the variable-degree case.

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MS66

Multigrid Methods for Degenerate and Singular Elliptic Equations

We present fast multilevel methods for the approximate solution of discrete problems that arise from the discretization of a class of general degenerate elliptic equations such as the fractional Laplacian—a nonlocal operator. To localize it, we solve a Dirichlet-to-Neumann-type problem via an extension operator, which requires incorporating one more dimension to the problem. Using a framework of Xu and Zikatanov, we prove nearly uniform convergence of a multilevel method that employs a line smoother.

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MS66

A Hierarchical Error Estimate for a Schrodinger-Type Operator

We provide a hierarchical error estimate for a Schrödinger operator with inverse square potential, and argue that it is efficient and reliable on a family of geometrically graded meshes. The potential term not only introduces new sources of singularities, but is also of the same order as the Laplacian, which makes the analysis more challenging. Numerical experiments demonstrate the efficacy of this approach. A direct comparison with adaptively refined meshes is also provided.

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MS66

A Posteriori Estimates and Adaptivity for Nonlinear Problems

In this talk, we will present an a posteriori error estimate for problems in 3D based on a hierarchical basis approach. This error estimator is developed for general linear elliptic problems and we will show its effectivity for nonlinear problems with singularities in the solution. I will also discuss extensions of the approach to geometric PDE.

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MS67

A Useful Factorization in PDE-constrained Distributed Optimal Control Problems

A distributed optimal control problem with a constraint of Poisson's equation is considered in order to develop an efficient numerical method and lead to further development for more complicated problems. A saddle point system that arises in the PDE-constrained optimization problem is solved using a useful factorization of a Schur complement. Two factors in the factorization, then, solved by the parallel linear solver, FETI-DPH. Scalability and regularization dependency study of FETI-DPH shows that the method is robust and versatile.

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MS67

Optimal Fishery Harvesting on a Nonlinear Parabolic Pde in a Heterogeneous Spatial Domain

The overexploitation of fisheries has called for an improved understanding of spatiotemporal dynamics of resource stocks as well as their harvesters. There is pressure to find methods for optimally solving these management problems. We use the tool of optimal control to investigate harvesting strategies for maximizing yield of a fish population in a heterogeneous, finite domain. We determine whether these solutions include no-take marine reserves as part of the optimal solution. The fishery stock is modeled using a nonlinear, parabolic partial differential equation with logistic growth, movement by diffusion and advection, and with Robin boundary conditions. The objective for the problem is to find the harvest rate that maximizes the discounted yield. Optimal harvesting strategies are found numerically.

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MS67

Optimal Control Applied in Coupled Within-host and Between-host Models

An immuno-epidemiological model is formulated and analyzed for a "within-host" system of ODEs coupled with a "between-host" system of PDEs and ODEs. Using the method of characteristics and a fixed point argument, we prove the existence and uniqueness of solution to our system. An optimal control problem for the coupled model is considered, and existence, characterization and uniqueness results established. A forward backward sweep numerical method is used to solve the optimality system.

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MS67

Multigrid Solution of Distributed Optimal Control

Problems Constrained by Semilinear Elliptic Pdes

We study a multigrid solution strategy for distributed optimal control problems constrained by semilinear elliptic PDEs. Working in the discretize-then-optimize framework, we solve the reduced optimal control problem using Newtons method. Further, adjoint methods are used to compute matrix-vector multiplications for the reduced Hessian. In this work we introduce and analyze a matrix-free multigrid preconditioner for the reduced Hessian which proves to be of optimal order with respect the discretization.

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MS68

Lymphatic Filariasis: Transmission Dynamics and Diagnostics During MDA

Lymphatic filariasis (LF) is a significant public health problem in many countries, especially Papua New Ginea (PNG) where the level of transmission by the mosquito vector, human infection rates and clinical morbidity are among the highest in the world. WHO launched its Global Program to Eliminate Lymphatic Filariasis (GPELF) in this region by 2020. Various reasons have been attributed to the failure of many countries to make progress, without substantive evidence. This study attempts to develop and analyze a mathematical model that captures the dynamics of Lymphatic Filariasis in PNG on which impact of the diagnostics methods and treatment programs can be studied. The population in the model is stratified based on the hosts microfilarial and antibody levels. The survival of the infected mosquitoes (vector) depends on the size of the load of microfilaria engorged. Data from Papua New Guinea are used to estimate the parameters, and understand the LF transmission dynamics. We compare the effect of the mosquitos mortality rate caused by the high microfilaria load on the reproduction number. Moreover, we identify conditions when vector control and mass treatment can be jointly or individually beneficial over time.

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MS68

Modeling Low and High Pathogenic Avian Influenza

This talk introduces and age-since recovery model of LPAI and HPAI in birds. Reproduction numbers ($\mathcal{R}_{\prime}^{\mathcal{L}\sqsupseteq}, \mathcal{R}_{\prime}^{\mathcal{H}\sqsupseteq}$) and invasion reproduction numbers ($\hat{\mathcal{R}}_{H_w}, \hat{\mathcal{R}}_{L_w}$) of LPAI and HPAI are computed. It is shown that the system has a unique disease-free equilibrium that is locally and globally stable if $\mathcal{R}_{\prime}^{\mathcal{L}\sqsupseteq} < \infty$ and $\mathcal{R}_{\prime}^{\mathcal{H}\sqsupseteq} < \infty$. If $\mathcal{R}_{\prime}^{\mathcal{L}\sqsupseteq} > \infty$ a unique LPAI dominance equilibrium exists. Similarly, if $\mathcal{R}_{\prime}^{\mathcal{H}\sqsupseteq} > \infty$ a unique HPAI dominance equilibrium exists. The equilibria are locally stable if $\hat{\mathcal{R}}_{H_w} < 1$ ($\hat{\mathcal{R}}_{L_w} < 1$ correspondingly). A unique coexistence equilibrium is present if both invasion numbers are larger than one. Simulations show that this coexistence equilibrium can lose stability and coexistence in the form of sustained oscillations is possible. Cross-immunity and duration of protection increase the probability of coexistence. Simulations also show that increasing LPAI transmission increases LPAI prevalence and decreases HPAI prevalence. This observation in part may explain why wild birds which have much higher transmission of LPAI compared to domestic birds also have much lower prevalence of HPAI.

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MS68

A Mathematical Approach to Skeletal Muscle and Insulin Sensitivity in Type 2 Diabetes

Studies on the role of exercise in regulating skeletal muscle metabolism and insulin action suggest that exercise increases insulin sensitivity and is associated with elevated expression of genes linked to metabolism. However, mechanisms underlying exercise and insulin sensitivity on gene expression are not well understood. A transcriptional network derived from experimental work and corresponding mathematical model of gene expression is proposed. We investigate dynamics of potential biological pathways and the role of key transcription factors.

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MS68

An Agent-Based Approach to Model Host Switching of Two Trypanosoma Cruzi Infected Triatomine Vector Species on Two Preferred Sylvatic Hosts

The parasite *Trypanosoma cruzi*, spread by triatomine vectors, affects over 100 mammalian species throughout the Americas, including humans, in whom it causes Chagas' disease. In the U.S., only a few cases have been documented of human infection by vectors, but prevalence is high in sylvatic hosts. Sylvatic transmission of *T. cruzi* is spread by Triatominae vector species biting hosts, creating multiple interacting vector-hosts cycles. We aim to quantify contacts between different host and vector species.

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MS69

Estimating Reactive Fluxes using an Analogy with Electric Circuits

The transition process between two metastable sets of stochastic system driven by a deterministic potential force and a small white noise can be quantified be a vector field called the reactive current. The reactive current coincides with the electric current for a properly defined electric flow. I propose a method for estimation of the percentages of the reactive current via a network of reactive channels exploiting this analogy.

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MS69

Free Energy Landscape and Kinetics of Particles with Short-Ranged Interactions

We propose a new way to look at particles interacting with short-ranged potentials (such as colloids), based on taking the limit as the range of the interaction goes to zero. In this limit, the landscape is entirely defined by geometrical manifolds plus a single control parameter, while the dynamics on top of the manifolds are given by a hierarchy Fokker-Planck equations coupled by "sticky" boundary conditions. We illustrate this theory with several applications, such as computing the low-dimensional manifolds, free energies, and transition rates for n¡=8 identical particles, comparing these to experiments with colloids, and enumerating rigid packings of hard spheres.

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MS69

Theory of Transition Path Process

Understanding rare events like transitions of chemical system from reactant to product states is a challenging problem due to the time scale separation. In this talk, we will discuss some recent progress in mathematical theory of transition paths. In particular, we identify and characterize the stochastic process corresponds to transition paths. The study of transition path process helps to understand the transition mechanism and provides a framework to analyze numerical approaches for rare event sampling and simulation.

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MS69

Geometry and Approximation of Intrinsically Low-Dimensional Dynamical Systems in High Dimensions

We introduce a novel technique for approximating stochastic systems in high-dimensions that have low-dimensional effective state spaces, by simpler stochastic systems that may be simulated very efficiently, and are learned only from configurations observed in short runs of the underlying system. We apply this construction to toy models and to molecular dynamics data. The construction does not require a priori knowledge of reaction coordinates.

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MS70

3D SAR Point Clouds

We present a new technique for the processing of SAR data for the accurate measurement of scattering center locations in three dimensions. Through the use of coherent SAR collections that form a sparse aperture, the approach produces a 3D point cloud, not dissimilar from lidar point clouds. In this talk we will present the background and technical development of the technique and present several examples of high-density point clouds derived from SAR data collections.

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MS70

Operator-theoretic Formulation of Radar Detec-

tion and Waveform Design Problems

Delay–Doppler processing of radar signals is naturally described in the language of Hilbert–Schmidt operators on L^2 spaces of signals. This perspective is developed, and some standard types of problems in detection and waveform design are shown to manifest in terms of questions about the spectra of such operators.

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MS70

Detection Theory for Multi-static Active and Passive Radar

This talk describes the detection problem for multi-static active and passive radar and proposes some new Bayesian detectors based on marginalisation over Grassmanian manifolds.

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MS70

Uncertainty Propagation in Radar, A System-Level Perspective

Abstract not available at time of publication.

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MS71

Probabilistic Conditioning Without Bayes

In this work we propose a method for constructing best approximations of spatially conditioned random vectors on finite order Wiener chaos spaces. Conditioning is achieved by an iterative algorithm, projecting alternatively on the constraints domain of interest and on the finite order chaos space. In many applications physical constraints require that uncertain parameters/fields are confined in a specific domain. Even though the Wiener chaos expansions of such random parameters maintain this property, truncated chaos expansions in principle do not, leading to instabilities of numerical methods. We circumvent this obstacle by solving a modified problem using appropriately best approximations of the conditioned random parameters.

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MS71

Representing High-Dimensional Random Variables from Data

In predictive modeling and simulations, one often needs to represent multi-dimensional random variables from data. Conventional methods such as kernel density estimation cannot handle high dimensions. Here we present a method based on normal copula model and polynomial chaos expansion, which allows one to represent high dimensional dependent non-Gaussian random variables.

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MS71

Model Reduction for Systems of Differential Equations with Initial Condition and Parametric Uncertainty

In many time-dependent problems of practical interest the initial conditions or parameters entering the equations describing the evolution of the various quantities exhibit uncertainty. One way to address the problem of how this uncertainty impacts the solution is to expand the solution using polynomial chaos expansions and obtain a system of differential equations for the evolution of the expansion coefficients. We present an application of the Mori-Zwanzig formalism to the problem of constructing reduced models of such systems.

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MS71

Reservoir Model Reduction Techniques for Uncertainty Quantification

Model reduction plays an important role in the practical assessment of uncertainty in reservoir production forecast. In this talk, we discuss the rationale for constructing coarser and simpler reservoir models and recently developed techniques, including new ideas on geologic modeling and more traditional model coarsening and upscaling techniques. In particular, the Dirichlet-Neumann representation (DNR) method for upscaling and multiscale simulation will be discussed in some detail.

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MS73

Numerical Approximation Methods for Non-Uniform Fourier Data

In this talk I discuss the reconstruction of compactly supported piecewise smooth functions from non-uniform samples of their Fourier transform. This problem is relevant in applications such as magnetic resonance imaging (MRI) and synthetic aperture radar (SAR). Two standard reconstruction techniques, convolutional gridding (the non-uniform FFT) and uniform resampling, are summarized, and some of the difficulties are discussed. It is then demonstrated how spectral reprojection can be used to mollify both the Gibbs phenomenon and the error due to the non-uniform sampling. It is further shown that incorporating prior information, such as the internal edges of the underlying function, can greatly improve the reconstruction quality. Finally, an alternative approach to the problem that uses Fourier frames is proposed.

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MS73

A Framework for Moving Least Squares Method with Total Variation Minimizing Regularization

In this study, we propose a computational framework to incorporate regularization terms used in regularity based variational methods into least squares based methods. By putting schemes from both approaches into a single framework, the resulted scheme benefits from the advantageous properties and overcomes the drawbacks of both parties. As an example, in this study, we propose a new denoising scheme where the total variation minimizing term is adopted by the moving least squares method and show numerical comparison.

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MS73

Blind One-Bit Compressive Sampling

In this talk, we introduce an optimization model for reconstruction of sparse signals from 1-bit measurements. The model targets a solution that has the least l0-norm among all signals satisfying consistency constraints stemming from the 1-bit measurements. An algorithm for solving the model is developed. Convergence analysis of the algorithm is presented. Our approach is to obtain a sequence of optimization problems by successively approximating the l0-norm and to solve resulting problems by exploiting the proximity operator. We examine the performance of our proposed algorithm and compare it with the binary iterative hard thresholding (BIHT) for 1-bit compressive sampling reconstruction. Unlike the BIHT, our model and algorithm does not require a prior knowledge on the sparsity of the signal. This makes our proposed work a promising practical approach for signal acquisition.

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MS73

Constructing Approximation Kernels for Non-Harmonic Fourier Data

Imaging modalities such as magnetic resonance imaging (MRI) and applications such as radio astronomy often require the reconstruction of signals from non-harmonic Fourier measurements. The Dirichlet kernel, which characterizes the approximation properties of harmonic Fourier reconstructions, is no longer applicable. This talk discusses the design of approximation kernels for non-harmonic Fourier reconstruction, incorporating features of the underlying signal such as compact support and piecewise smoothness. Numerical results and applications to convolutional gridding reconstructions as well as jump and edge detection in one and two dimensions will be presented.

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MS74

Mimetic Finite Difference PDE Based Models in Image Processing

We introduce the use of mimetic methods to the imaging commu- nity, for the solution of the initial-value problem ubiquitous in the machine vision and image processing and analysis elds. PDE-based image processing and analysis techniques comprise a host of applica- tions such as noise removal and restoration, deblurring and enhance- ment, segmentation, edge detection, inpainting, registration, motion analysis, etc. In these applications, the digital images are given on discrete (regular) grids. This lends itself for discretizing the PDEs to obtain numerical schemes that can be solved on a computer. Because of their favorable stability and eciency properties, semi-implicit - nite dierence and nite element schemes have been the methods of choice (in that order of preference). We propose a new approach for the numerical solution of these problems based on mimetic methods.

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MS74

Mimetic Discretization Methods

Mimetic Operators satisfy a discrete analog of the divergence theorem and they are used to create/design conservative/reliable numerical representations to continuous models. We will present a methodology to construct mimetic versions of the divergence and gradient operators which exhibit high order of accuracy at the grid interior as well as at the boundaries. As a case of study, we will show the construction of fourth order operators in a one-dimensional staggered grid. Mimetic conditions on discrete operators are stated using matrix analysis and the overall high order of accuracy determines the bandwidth parameter. This contributes to a marked clarity with respect to earlier approaches of construction. We present theoretical aspects of a mimetic method based on the extended Gauss Divergence Theorem as well as examples using this methods to solve partial differential equations.

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MS74

GPU Acceleration of a Fourth-order Mimetic Finite Difference Method for Elastic Wave Propagation

In this work, we use GPU (Graphics Processing Unit) to accelerate a previously tested serial fourth-order mimetic finite-difference method to computationally simulate 2-D elastic motion subject to a free surface boundary condition. The mimetic discretization of the underlying mathematical model, linear elastodynamics in the interior and a Newmann-type boundary condition at the free surface (zero traction), is performed on a staggered grid and employs central stencils (at interior) and lateral stencils (at the free surface). It avoids the location of grid points beyond the physical boundary that makes the original method memory-saving and very precise. Here, we describe the new CUDA implementation of this method on NVIDIA Tesla C2050 graphics card and detail the optimized use of registers and fast shared memory to accelerate the computational performance. Our preliminary results show an improvement factor above 15% with respect to the performance of the serial version when using very dense (data size up to memory card capacity 3 GB) and fine (10 grid points sampling minimum S wavelength ?Smin along propagating distances of 300?Smin) grids. These encouraging results motivate us to generalize this method's GPU implementation to 3-D rectangular meshes making it more suitable for realistic seismic propagation problems.

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MS74

Advances in the Development of the Mimetic Methods Toolkit (MTK): An Object-Oriented API for Mimetic Discretization Methods

The Mimetic Methods Toolkit (MTK) is an Application Programming Interface that allows for an intuitive implementation of Mimetic Discretization Methods (MDMs) for the solution of Partial Differential Equations. The MDMs yield numerical solutions that guarantee an uniform order of accuracy, while ensuring the satisfaction of conservative laws. The MTK is developed in C++, thus exploiting the advantages of the Object Oriented programming paradigm. We present example problems, and the advantages and design of the MTK.

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MS75

Efficient Implementation of the Hardy-Ramanujan-Rademacher Formula

It is well known that the Hardy-Ramanujan-Rademacher (HRR) formula allows efficiently evaluating the integer partition function p(n) for large n. We investigate theoretical and practical aspects of implementing the HRR formula, and show that quasi-optimal complexity for computing p(n) can be achieved. With a new implementation, which runs more than 500 times faster than previously published software, we have computed several billion Ramanujan-type congruences, greatly extending tables previously computed by Weaver.

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MS75

Symbolic Computation and Modular Forms

The talk reports on recent developments arising from joint work with Silviu Radu (RISC). This, for instance, includes a new unified computational framework for proving Ramanujan's celebrated partition congruences modulo powers of 5, 7, and 11.

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MS75

A Solution of Sun's $520 Challenge Concerning 520/pi

Series for $1/\pi$ and their relation to modular forms have a long history going back to Ramanujan. We will review this connection and give a brief account of the history. We then indicate how to prove a Ramanujan-type formula for $520/\pi$ that was conjectured by Zhi-Wei Sun. A key ingredient is a hypergeometric representation of the relevant double series, which relies on a recent generating function for Legendre polynomials by Wan and Zudilin. This is joint work with Mathew Rogers.

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MS75

Differential Equations, Belyi Maps, and Modular Curves

Let L be a homogeneous linear differential equation with polynomial coefficients. L is called a CIS equation if it has a non-zero Convergent Integer power Series among its solutions. All known CIS equations of order 2 are solvable in terms of hypergeometric functions; they have solutions of the form r0 h + r1 h' where h = 2F1(a,b;c | f), and r0, r1, f are algebraic functions. A key step to find such a solution is to construct the function f, which is often a Belyi map. If f is a rational function then we can use recent algorithms by T. Fang and V. Kunwar and the classification in arXiv:1212.3803. An example where f is not a rational function is the generating function of the Apery numbers, listed at oeis.org/A005259. A non-rational f has at least one conjugate g not equal to f. Then f,g satisfy an algebraic relation P(f,g)=0. Our strategy to classify all non-rational f's is to classify these relations P. It turns out that equations for the modular curve X0(N) provide such P.

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MS76

Scaling of High Dimensional Function Approximation

High dimensional function approximation can arise in a diverse number of circumstances and we specifically focus on the applications of uncertainty quantification and data analysis to demonstrate fast scalable methods that can capture piecewise smooth functions in high dimensions with high order accuracy and low computational burden. Within the field of uncertainty quantification, the developed methods can be used for both approximation and error estimation of stochastic collocation methods where computational sampling can either be guided or come from a legacy database. High dimensional function approximation can also be used in hierarchical data analysis of large, possibly distributed data, to represent statistics of data in a compact form.

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MS76

Numerical Solutions for Stochastic Stokes Equations with White Noise Loading Terms

The nonlinear filter problem can be classified as an inverse problem of identifying the state of a system with noise perturbation given an observation of the system, also perturbed by noises. Traditional numerical simulation methods include unscented Kalman filter and particle filter. In this talk, we attempt to construct efficient numerical methods using forward backward stochastic differential equations and implicit function theory. Numerical experiments demonstrate that our methods are more accurate than Kalman filter and more stable than the particle filter.

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MS76

The Mixed Finite Element Method for Parameter Identification in Porous Media

We analyze a stochastic inverse problem in porous media, using the mixed finite element method. We estimate statistical moments (mean value, variance) of input data, given the PDF of quantities of physical interest, by using several identification objectives. We prove the existence of an optimal solution, establish the validity of the Lagrange multiplier rule, obtain a stochastic optimality system of equations, provide error estimates and illustrate the theoretical results with numerical examples.

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MS76

Sensitivity and Uncertainty

While intelligent sampling methods such as sparse grid collocation has expanded the class of random systems that can be simulated to aid uncertainty quantification, the statistical characterization of the model parameters are rarely known. We use the Fréchet derivative to determine the most significant parametric variations and generate a low order family of linearizations of the input-output mapping, which is used in the parameter identification problem. We illustrate our methods with a numerical example.

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MS77

A Spatially Adaptive Iterative Solution of Nonlinear Operator Eigenproblems

We present a new algorithm for the iterative solution of nonlinear operator eigenvalue problems arising from partial differential equations. This algorithm combines Chebfun-style automatic spatial resolution of linear operators in coefficient space with the infinite Arnoldi method for nonlinear matrix eigenproblems.

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MS77

Chebfun and Quadrature

Chebfun is an open-source Matlab-based software system that extends familiar methods of numerical computation involving numbers to continuous analogues for functions. This talk discusses Chebfun's fast capabilities for Clenshaw–Curtis, Gauss–Legendre, –Jacobi, –Hermite, and –Laguerre quadrature, based on algorithms of Waldvogel, Hale and Townsend, and Glaser, Liu, and Rokhlin. We show how such methods can be applied to quadrature problems, including: integrals over rectangles, fractional derivatives, functions on unbounded intervals, and fast computation of barycentric weights.

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MS77

Chebfun2: Extending Chebfun to Two Dimensions

An object-oriented MATLAB system is described that extends the capabilities of Chebfun to smooth functions of two variables defined on rectangles. Bivariate functions are approximated to essentially machine precision by using iterative Gaussian elimination with complete pivoting to form chebfun2 objects representing low rank approximations. Fundamental operations such as integration, evaluation, and global optimization are described along with numerical examples.

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MS77

Chebfun and Approximation Theory

Chebfun is all about connecting ideas and theorems of approximation theory with practical numerical computations. We present some of the highlights in this area.

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MS78

Fast Algorithms for Some Inverse Problems in Medical Imaging

We review here some fast numerical techniques for reconstructions in medical imaging modalities (mainly diffuse optical tomography, optical molecular imaging and quantitative photoacoustic tomography) that are based on the radiative transport equation. The methods presented rely on the combination of preconditioning, precomputation and interpolation of solutions of the forward transport equation, as well as the structures of the specific inverse problems.

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MS78

Marriage and Mathematics of Computed Tomography and Magnetic Resonance Imaging

Omni-tomography is enabled by interior tomography that has been developed over the past five years. By omni-tomography, we envision that the next stage of biomedical imaging will be the grand fusion of many tomographic modalities into a single gantry (all in one) for simultaneous data acquisition of numerous complementary features (all at once). This integration has great synergistic potential for development of systems biology, personalized and preventive medicine, because many physiological processes are dynamic and complicated, and must be observed promptly and comprehensively. In this perspective, we first present the background for and power of omni-tomography, and then discuss a top-level design for the first CT-MRI scanner as a simplified omni-tomographic machine. An important application of the CT-MRI scanner is for vulnerable plaque characterization known as a holy grail of cardiology, which might bring us exciting collaborative opportunities.

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MS78

Towards the Clinical Implementation of Iterative Cone-beam CT Reconstruction for Radiation Therapy using a Multi-GPU System

An iterative cone beam CT (CBCT) reconstruction system is developed on a quad-GPU workstation. The least square step is accelerated by distributing the forward and backward projection operations among GPUs according to projection angle. The regularization step is accelerated by having each GPU processing a sub-volume. A parallel-reduction algorithm is employed to accumulate data at GPUs. High quality CBCT images for various real clinical applications can be obtained. Efficiency gain is also analyzed.

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MS78

Variable Step Lengths and Line Search for Nonsmooth Image Reconstruction

Despite a burst of advances in optimization algorithms recently for nonsmooth image reconstructions, e.g. using total variation as regularization, the algorithms either does not work, or works with extremely low efficiency, for most real-world image reconstruction problems such as those from medical imaging. The low efficiency is usually due to the very restrictive constraint on step lengths when some subproblems are approximately solved in each iteration. We introduce a new algorithm with nonmonotone line search strategy that can automatically tune step lengths to significantly boost the overall convergence with low search cost. The improvements are demonstrated on various medical image reconstruction problems.

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MS79

Using In Vitro Data to Predict Pathway-Based Effects of Environmental Chemicals

Abstract not available at time of publication.

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MS79

Next Generation Thermal Management of Buildings

This project explores next-generation, environmentally-friendly cooling and heating of buildings. We explore the thermal properties of an idealized house, focusing on passive heat losses, solar gain and passive cooling. We discuss heat exchange through phase change materials (PCM). We further discuss model refinements which would be useful in building design, selection of materials and in optimizing building management.

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MS79

Attributing Tropospheric Ozone Formation to Precursor Sources Considering Nonlinear Chemistry

Abstract not available at time of publication.

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MS79

Developing Algorithms to Distinguish and Classify Locations Based on Their Weather Sensitivity

Abstract not available at time of publication.

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MS80

Stability and Phase Transition in the Kuramoto Model of Coupled Oscillators

We consider the Kuramoto system of coupled oscillators, a model for synchronization and related phenomenon. We prove an index theorem which counts the dimension of the unstable manifold to a stationary solution, and use this to prove the existence of a phase transition in the limit of a large number of oscillators. Interestingly this phase transition does not occur in the scaling primarily considered in the previous literature, but in a slightly different scaling.

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MS80

Instability Indices for Matrix Pencils

There is a well-established instability index theory for linear and quadratic matrix pencils for which the coefficient matrices are Hermitian and skew-Hermitian. This theory relates the number of negative directions for the Hermitian matrix coefficients to the total number of unstable eigenvalues for the pencil. We extend the theory for alternating pencils of any finite degree, and derive quite general results. We also consider Hermitian pencils, and derive some results for cases in which the coefficient matrices satisfy certain definiteness properties.

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MS80

Colliding Convectons

Convectons are strongly nonlinear, spatially localized states found in thermally driven fluid flows. In a horizontal layer with up-down symmetry odd parity convectons are stationary. When this symmetry is broken these states drift. Direct numerical simulations are used to study head-on and follow-on collisions between drifting convectons in binary fluid convection (Mercader et al., J. Fluid Mech. 722 (2013) 240), and the results compared with the corresponding dynamics in a Swift-Hohenberg model.

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MS80

Competitive Instability and Geometric Evolution in Amphiphilic Systems

Amphiphilic systems possess a surfactant phase which lowers overall free energy by wetting interfacial structures. Unlike classical phase separating systems, such as modeled by the Cahn-Hilliard free energy, which are dominated by single-layer interfaces, amphiphilic systems support a wide range of coexisting structures, including bilayers, pore networks, pearled pores, and micellular structures. We model the amphiphilic systems through the Functionalized Cahn-Hilliard free energy, and show that competition between structures is mediated through the far-field chemical potential. We analyze this competition, showing it can lead to instabilities and deriving the coupled geometric evolution of mixed states.

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MS81

Polynomials with No Zeros on a Face of the Bidisk

Abstract not available at time of publication.

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MS81

Christoffel Functions and Universality Limits for Multivariate Orthogonal Polynomials

Abstract not available at time of publication.

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MS81

On Koornwinder Bivariate Orthogonal Polynomials

Abstract not available at time of publication.

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MS81

The C-Function Expansion of the Multivariable Basic Hypergeometric Function

Abstract not available at time of publication.

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MS82

A Two-Phase Augmented Lagrangian Filter

Method

We develop a new active-set method whose main computational effort can be built on scalable parallel solvers. Our two-phase method consists of a first phase in which we approximately minimize the augmented Lagrangian to estimate the optimal active set. In the second phase, we solve an equality-constrained QP. An augmented Lagrangian filter determines the accuracy of the augmented Lagrangian minimization and ensures global convergence. We present a convergence analysis and preliminary numerical results.

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MS82

Continuous Method Models for Quadratic Programming with Bound Constraints

In this talk, some continuous method models for quadratic programming problems with bound constraints are introduced. The main components for these models are some simple dynamical systems which only involve matrix vector multiplications. Therefore these new models are suitable for large-scale problems. Based on these models, various theoretical properties including the strong convergence of these dynamical systems will be explored and addressed. Some preliminary numerical results are presented to illustrate the attractiveness of these new models.

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MS82

On Solving L-BFGS Trust-Region Subproblems

We present a new method called the Moré-Sorensen Sequential (MSS) method for computing the minimizer of a quadratic function defined by a limited-memory BFGS matrix subject to a two-norm trust-region constraint. This solver is an adaptation of the Moré-Sorensen direct method into a L-BFGS setting for large-scale optimization. The MSS method uses a recently proposed fast direct method for solving large shifted BFGS systems of equations.

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MS82

Primal-Dual Regularized Methods for Nonlinear Programming

We present a regularized method for solving general quadratic programs (QP). The method solves a sequence of bound-constrained subproblems in the primal-dual variables, which involve the solution of a regularized KKT system. It can be shown that in the convex case, the solution of the bound-constrained subproblem is also a solution of a QP subproblem for a stabilized sequential quadratic programming (SQP) method. Numerical results are presented for the method.

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MS83

Sensor Geometry

From the perspective of estimation performance, rather than data collection, after C.R. Rao, Amari, and others, a sensor may be characterized as a Riemannian manifold where the metric is the Fisher Information. Here we consider the issue of changing sensors and how to analyse the resulting collection of Riemannian manifolds. It transpires that, subject to some reasonable hypotheses, such collections of sensors can themselves be naturally parametrized by a Riemannian manifold. We discuss the calculation of geodesics on this manifold for some simple cases.

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MS83

Radar Imaging Work at MIT Lincoln Laboratory

Abstract not available at time of publication.

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MS83

Radar Waveform Design

Abstract not available at time of publication.

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MS83

Statistical and Analytical Techniques in Synthetic Aperture Radar Imaging

We present a synthetic-aperture radar inversion scheme (correlation SAR imaging) that performs data preprocessing in which we correlate pairs of received data with different slow-time values and frequencies. It is found that the point-spread function (PSF) of the image-fidelity operator has a narrower main lobe and also reduced sidelobes when compared to the standard SAR PSF. It is shown that when data pairs are chosen carefully the effect of volume scattering clutter is mitigated.

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MS84

Fast Linear Algebra for Stochastic Inversion in Large-Scale High-Dimensional Complex Systems

Large scale inverse problems, which frequently arise in engineering applications, involve estimating unknowns from sparse data. The goal is to evaluate the best estimate, quantify the uncertainty in the solution, and obtain conditional realizations. Traditional Bayesian approaches to obtain the above, suffer from the fact that the method becomes computationally expensive, when the number of unknowns is large; typically scaling as the square or cube of the number of unknowns, and thereby making it computationally intractable. In this talk, I will present fast linear algebra techniques based on fast multipole method and hierarchical matrices that reduce the computational complexity to almost linear complexity. This new technique is applied to a realistic large scale stochastic inverse problem arising from a cross-well seismic tomography application.

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MS84

Bayesian Treed Multivariate Gaussian Process for Uncertainty Quantification

Computer experiments (numerical simulations) are widely used in scientific research to study and predict the behavior of complex systems, which usually have responses consisting of a set of distinct outputs. The computational cost of the simulations at high resolution are often expensive and become impractical for parametric studies at different input values. To overcome these difficulties we develop a Bayesian treed multivariate Gaussian process (BTMGP) as an extension of the Bayesian treed Gaussian process (BTGP) in order to model and evaluate a multivariate process. A suitable choice of covariance function and the prior distributions facilitates the different Markov chain Monte Carlo (MCMC) movements. We utilize this model to sequentially sample the input space for the most informative values, taking into account model uncertainty and expertise gained. A simulation study demonstrates the use of the proposed method and compares it with alternative approaches.

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MS84

CDF Solutions of Nonlinear Hyperbolic Equation with Uncertain Parameters

Uncertainty is everywhere, from the nuclear reactors, material discovery to reactive transport in heterogeneous porous media. Quantifying the uncertainty associated with the parameters in complex systems is critical, which can help us to verify our modern simulation codes and assess confidence levels. Our aim is to use accurate computational simulations to predict the behavior of complex systems. The importance of uncertainty quantification has been recognized by the computational science and engineering communities. Many stochastic algorithms and techniques have been developed. The explosion in computational effort associated with the large number of random dimensions is often prohibitive, even for modern supercomputers. As such, advanced stochastic approximation techniques are necessary to minimize the complexity of mathematical models and make numerical solutions feasible. This minisymposium will explore recent advances in numerical algorithms and applications for uncertainty quantification, model reduction, and stochastic inversion in large-scale high-dimensional complex systems.

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MS84

Improved Diffusion Monte Carlo for Quantum Monte Carlo, Rare Event Simulation, Data Assimilation, and More

Diffusion Monte Carlo (DMC) is a workhorse of stochastic computing. It was invented forty years ago as the central component in a Monte Carlo technique for estimating various characteristics of quantum mechanical systems. Since then it has been used in applied in a huge number of fields, often as a central component in sequential Monte Carlo techniques (e.g. the particle filter). DMC computes averages of some underlying stochastic dynamics weighted by a functional of the path of the process. The weight functional could represent the potential term in a Feynman-Kac representation of a partial differential equation (as in quantum Monte Carlo) or it could represent the likelihood of a sequence of noisy observations of the underlying system (as in particle filtering). DMC alternates between an evolution step in which a collection of samples of the underlying system are evolved for some short time interval, and a branching step in which, according to the weight functional, some samples are copied and some samples are eliminated. Unfortunately for certain choices of the weight functional DMC fails to have a meaningful limit as one decreases the evolution time interval between branching steps. We propose a modification of the standard DMC algorithm. The new algorithm has a lower variance per workload, regardless of the regime considered. In particular, it makes it feasible to use DMC in situations where the “naive’ generalization of the standard algorithm would be impractical, due to an exponential explosion of its variance. We numerically demonstrate the effectiveness of the new algorithm on a standard rare event simulation problem (probability of an unlikely transition in a Lennard-Jones cluster), as well as a high-frequency data assimilation problem. We then provide a detailed heuristic explanation of why, in the case of rare event simulation, the new algorithm is expected to converge to a limiting process as the underlying stepsize goes to 0.

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MS85

Towards Least Squares Sensitivity Analysis of Chaotic Fluid Flows

We present the least squares sensitivity analysis method of computing sensitivity derivatives of long time averaged quantities in chaotic dynamical systems. This method is based on linearizing the least squares problem of the governing equation, instead of the ill-conditioned initial value problem. We demonstrate least squares-based sensitivity computation on a variety of chaotic systems, and its application in optimization and error estimation.

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MS85

Multi-Level Dynamical Systems: Connecting the Ruelle Response Theory and the Mori-Zwanzig Approach

We consider the problem of deriving approximate autonomous dynamics for a number of variables of a dynamical system, which are weakly coupled to the remaining variables. We show that by using the Ruelle response theory on such a weakly coupled system it is possible to construct a surrogate dynamics, such that the expectation value of any observable agrees, up to second order in the coupling strength, to its expectation evaluated on the full dynamics. We then show that such surrogate dynamics agree up to second order to an expansion of the Mori-Zwanzig projected dynamics. This implies that the parametrizations of unresolved processes suited for prediction and for the representation of long term statistical properties are closely related, if one takes into account, in addition to the widely adopted stochastic forcing, the often neglected memory effects.

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MS85

Estimating Uncertainties in Statistics Computed from Simulations of Chaotic Systems

We propose an extension of Richardson extrapolation that can be applied to simulation outputs that are affected by sampling error, such as statistical outputs from simulations of chaotic systems. The method involves a direct estimate of the sampling error that is used to formulate a Bayesian inverse problem to infer parameters of a discretization error model. The process is demonstrated on the Lorenz equations as well as DNS of a $Re_\tau = 180$ channel flow.

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MS85

Challenges in Sensitivity Analysis and Uncertainty Quantification of Chaotic Systems

Many dynamical systems of scientific and engineering importance are chaotic. These chaotic systems can be found in unsteady fluid flows, our climate system and molecular dynamics. In these systems, it is interesting to compute the derivative of output quantities of interest to input parameters. These sensitivity derivatives are useful in many aspects of computational engineering, including optimization, uncertainty quantification, statistical inference, error estimation and mesh adaptation. However, we show that existing methods for sensitivity analysis, including the tangent linear method and the adjoint method, often fail in chaotic systems. The inability to exchange a limit and a derivative is the mathematical reason of this failure. We present analysis of the challenge and potential methods for overcoming it.

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MS86

Immunity Consequences of Crispr-Induced Host-Viral Co-Evolution

A new form of adaptive immune defense has recently been discovered in bacteria and archaea (known as CRISPR) where hosts acquire resistance from genetic material of infecting viruses. We show using an eco-evolutionary model how CRISPR-induced resistance facilitates the emergence and fluctuation of distributed immunity (DI) - the extent to which immunity is due to a diversity of alleles. Our findings suggest novel ways host-viral interactions are linked to complex population structure.

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MS86

Computational and Statistical Models for Detecting Natural Selection in Humans

New sequencing technologies have revolutionized the field of population genetics since sequencing whole genomes is now faster and cheaper. However, in order to get maximal benefit from the data one needs to combine better statistical estimators of mutation frequencies with detailed mathematical models that enables the inference of demographic and natural selection parameters. I will discuss these approaches in an application to find the genetic basis for adaptation to high altitude in Tibetans.

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MS86

A Multi-Scale Mathematical Model of Aspergillus Fumigatus in the Airway

The innate immune response to exposure to the ubiquitous fungus Aspergillus fumigatus, the causative agent of invasive aspergillosis, is complex, and involves mechanisms at several spatial scales, from molecular networks inside different types of cells to tissue-level and organism-level phenomena. This talk will describe a multi-scale mathematical model of the immune response that incorporates both important aspects of the host response as well as the fungus.

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MS86

Dynamics of an mRNA-Protein Model with Delay

In this talk I will describe a dynamical systems approach for the study of a mRNA-protein model that incorporates negative feedback, nonlinear interactions, and delays. I will show how the DDE system undergoes an important transition from equilibrium to oscillations via a Hopf bifurcation. The final outcome results in closed form expressions for the limit cycle amplitude and frequency of oscillation, which are then used to prove that delays can drive oscillations in gene activity.

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MS87

Finite Difference Modeling of Rupture Propagation under Velocity-dependent and Thermal Weakening Processes

In this work, we conduct finite difference simulations of mode II dynamic ruptures along a straight interface (fault) within a 2-D elastic medium where the constitutive friction law accounts for a strong weakening behavior of the friction coefficient at high velocities and the thermal pressurization of pore fluid. Thus, the mathematical model is given by linear elastodynamics at off-fault points combined to non-linear boundary conditions at the sliding interface. In our numerical implementation, we use as a starting point the fourth-order Mimetic Operators with Split-Nodes (MOSN) method for rupture simulations on velocity-and-state frictional interfaces that applies an implicit Euler integration of the semi-discrete elastic-fault system which is highly stiff at early stages of rupture propagation. Here, we add a semi-analytical integration of the coupled diffusion equations for temperature and pore pressure evolution.

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MS87

Low Dispersive Mimetic Modeling of Rayleigh Waves on Partly Staggered Grids

In elastic media, current finite difference (FD) implementations of free surface boundary conditions on partly staggered grids (PSG) use the highly dispersive and low accurate vacuum formulation. So called because the physical boundary is replaced by a thin vacuum grid layer where material parameters are practically zeroed at grid points (null Lame constants at stress nodes and density 0.001 kg m-3 at displacement nodes) and surface displacements are computed by the discretized interior elastodynamics. In this work, we enhance a 2-D PSG by the inclusion of Compound nodes (stress-displacement grid points) along a flat free surface boundary and use lateral mimetic second-order FD discretization of the exact zero-traction conditions to calculate surface displacements. At interior grid points, spatial discretization replicates existent PSG schemes and applies mimetic fourth-order staggered FD along cell diagonals, while nodal second-order FD allows progressing wavefields in time.

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MS87

High-Order Mimetic Modelling of 3D Surface Waves

We present a mimetic approach to the modelling of 3D elastic seismic waves in the presence of topography. The finite-difference computational grid is smoothly deformed in order to honor the topography. By using high-order Castillo-Grone operators, the free-surface condition can be accurately fulfilled. Consequently, the number of points required to model a desired wavelength remains low. This is of crucial importance when performing large-scale simulations of seismic waves in rough hilly terrains.

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MS88

Second-order Convex Splitting Schemes for the Periodic Nonlocal Cahn-Hilliard and Allen-Cahn Equations

We devise second-order accurate, unconditionally uniquely solvable and unconditionally energy stable schemes for the nonlocal Cahn-Hilliard (nCH) and nonlocal Allen-Cahn (nAC) equations for a large class of interaction kernels. We prove the unconditionally solvability and energy stability. We also present numerical evidence that both schemes are convergent, and in the case of the nAC equation, a proof of convergence can be carried out. Finally we demonstrate the performance of our algorithms by simulating nucleation and crystal growth for several choices of interaction kernels.

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MS88

A High-Performance Solution to the Functionalized Cahn-Hilliard Equation

The Functionalized Cahn-Hilliard (FCH) equation in three dimensions, $u_t = \Delta(\epsilon^2\Delta - W'(u) + \epsilon^2\eta)(\epsilon^2\Delta u - W'(u))$, describes pore network formation in a functionalized polymer/solvent system. The physical process is defined by multiple time-scales, requiring very long, accurate simulations to correctly describe the physics. We use a Fourier spectral method in space with an exponential time integrator to obtain a fast, numerically stable, and time-accurate method for solving the FCH equation. Numerical results on a GPU show a 10x speedup over a fully-parallelized eight-core CPU.

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MS88

A Thermodynamically Consistent Algorithm for Liquid-Vapour Phase Transition

In this work, novel numerical technologies are developed for multiphase flow problems with particular focus on the isothermal Navier-Stokes-Korteweg equations. First, in the presence of a non-local surface energy term, entropy variables are generalized to a functional definition. It will be shown that the weighted residual formulation in terms of the functional entropy variables leads to an unconditionally energy stable semi-discrete formulation. Second, a family of new quadrature rules is developed with the aim of generating new temporal discretizations. This time integration methodology enjoys several appealing features: (1) the nonlinear stability of the semi-discrete scheme is inherited at the fully discrete level; (2) the time accuracy is second-order; (3) there is no convexity requirement for the entropy function. A comprehensive set of numerical examples is studied to examine the aforementioned theories.

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MS88

A Gradient Stable Numerical Method For The Functionalized Cahn-Hilliard Equation

I will discuss a nonlinear semi-implicit numerical scheme for a high order nonlinear diffusive phase field model equation describing phase transformation and porous network formation in a functionalized polymers and solvent system. The modeling equation is highly nonlinear and stiff, therefore very restrictive on time step size for explicit numerical simulation. The physical process has two different scales: early phase separation, which requires accuracy in both time and space discretization; late porous network combination and slow evolution to steady state, which demands the simulation to be run for a long range of time. The scheme we shall discuss is unconditionally gradient stable, therefore allowing adaptive time step strategy for the accurate and fast simulation of the physical process while preserving the discrete energy law. The scheme is designed by splitting the chemical potential in an explicit-implicit fashion based on contraction and expansion of gradient components.

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MS89

Tools for Social Media

Abstract not available at time of publication.

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MS89

More Tools for Social Media

I will discuss how and why social media can be useful for a researcher, both as a consumer and a contributor, drawing on my own experiences of using Twitter and blogging with Wordpress. I will also discuss how SIAM is using social media.

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MS89

Maintaining An Online Publication List

Abstract not available at time of publication.

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MS89

SIAM's New Online Community Platform

Abstract not available at time of publication.

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MS90

Investigation of Iterative Image Reconstruction for X-Ray Phase-Contrast Imaging

X-ray phase-contrast (XPC) computed imaging methods are rapidly emerging and hold great potential for biomedical imaging. A compelling advantage of XPC imaging over conventional radiographic methods is that it does not rely solely on X-ray attenuation contrast and is sensitive to the refractive and small-angle scattering properties of tissues. In this work, we describe iterative algorithms for reconstructing volumetric images of tissue properties from knowledge of noisy and/or incomplete measurement data.

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MS90

Adaptive Algorithms for Accelerated Dynamic MRI

We introduce adaptive parametric image representations to represent dynamic MRI signal. The parameters and the representation are simultaneously estimated from the under-sampled measurements. Since the number of degrees of freedom of this model is much smaller than that of current low-rank and compressed sensing methods, this scheme provides improved reconstructions for datasets with considerable inter-frame motion. The utility of different dictionary constraints and penalties on the coefficients are explored to further improve the reconstructions. Numerical comparisons of the proposed scheme with classical methods demonstrate the significant improvement in performance in the presence of motion.

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MS90

Dose Shaping and Carving - Utilizing Sparsity and Learning

Treatment planning in radiotherapy is a multi-objective optimization problem, with various objectives and unknown balancing. The dose map and the control fluence variables relate via a linear system, analogous to CT reconstruction. Our work addresses these issues from two perspectives: (1) various sparsity objectives are introduced to enable dose shaping and carving, based on desired dose properties; and (2) a learning approach with approximate consistency to automate balancing the various objectives in the composite optimization.

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MS90

Source Recovery in RTE-based Bioluminescent Tomography

As one of the new emerging optical molecular imaging modalities, bioluminescence tomography is to reconstruct the light distribution inside a small animal body from the measured photon data on its surface. Such light distribution can either be generated by external light sources (DOT), or by internal bioluminescent source (BLT), both of which can be described by the radiative transfer equation (RTE). In this paper, we consider the BLT source recovery problem of RTE. The model is constructed to minimize the difference between a predicted distribution and the light distribution generated by a predicted source within the body, together with the difference between the predicted distribution and the data measured on boundary. The total variation of the light source is taken as one of the regularization term so that the minimization of surface area of a light source is achieved. We apply the alternating direction multiplier method to decouple the system governing the light distribution and source data. A Projected Uzawa method and Alternating Lagrangian Multiplier Method are apply to minimize the total variation regularization term.

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MS91

A Loosely Coupled Scheme for Fluid Structure-Structure Interaction with Application to Blood Flow

The speaker will talk about modeling and simulation of FSI between an incomprensible, viscous fluid and a structure composed of several layers: a thin layer modeled by the membrane or shell equations, and a thick layer modeled by the equations of 2D or 3D elasticity. A stable loosely coupled scheme, called the kinematically coupled beta-scheme, will be introduced. Stability and convergence will be discussed, and numerical examples will be presented.

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MS91

Algorithms Composition Approach Based on Difference Potentials Method

In this talk we will discuss an efficient and flexible Algorithms Composition Framework for the elliptic and parabolic problems in composite and complex domains. The elliptic and parabolic equations which will be studied in this work serve both as the simplified models, and as the first step towards future development of the proposed framework for more realistic systems of materials, fluids, or chemicals with different properties in the different domains. The developed Algorithms Composition Framework can handle the complex geometries of the domains without the use of unstructured meshes, and can be employed with fast Poisson solvers. Our method combines the simplicity of the finite difference methods on Cartesian meshes with the flexibility of the Difference Potentials method. The proposed framework is very well suited for parallel computations as well, since most of the computations in each domain are performed independently of the others. Some numerical results to illustrate the accuracy and the efficiency of the developed method will be presented as well.

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MS91

Solving PDEs in Dynamic, Complex Geometries: The Diffuse Domain Method

Abstract not available at time of publication.

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MS92

Relaminarization of Turbulent Channel Flow by

Pre-determined Control

Abstract not available at time of publication.

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MS92

Well-Posedness of Supersonic and Transonic Characteristic Discontinuities in Two-Dimensional Steady Compressible Euler Flows

We present several important physical problems involving strong vortex sheets/entropy waves and discuss global well-posedness (existence in Bounded Variation space and L^1-stability) of these characteristic discontinuities for two-dimensional steady supersonic and transonic Euler flows using the wave front tracking method. Our results indicate that steady vortex sheets/entropy waves in these flows, as time-asymptotics, are stable in structure globally, in contrast with the prediction of the instability of these waves at high Mach numbers as time evolves. Some related control problems will be discussed. This is joint work in part with Gui–Qiang G. Chen (University of Oxford) and Hairong Yuan (East China Normal University).

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MS92

Optimally Controlling Unsteady Shock Waves

This talk will demonstrate formulation of unsteady shock wave attenuation as an optimal control problem. An adjoint-based shooting algorithm is used to satisfy all first-order necessary optimality conditions. Distributed control solutions with certain physical constraints are calculated for attenuating blast waves similar to those generated by Ignition Over Pressure (IOP) from the Shuttle's Solid Rocket Booster during launch. Results are presented for attenuating shocks traveling at Mach 1.5 and 3.5 down to 85%, 80% and 75% of the uncontrolled wave's driving pressure.

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MS92

Identifying Random Parameters Through Parallel Inversion

The incorporation of parametric uncertainty in the simulation of complex physical phenomena has become common practice. Yet, exact stochastic descriptions of these model parameters are often unknown and must be estimated from measurements of related model outputs. We present a sampling-based method for the identification of distributed stochastic parameters that lends itself more readily to parallel implementation than it's Bayesian counterpart, while allowing for more adaptivity than related optimization-based methods. Numerical examples are included.

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MS93

Streaming Singular Value Computations on GPU Platforms

Graphics processing units provide a significant computational advantage over traditional CPUs, but they present challenges due to their relatively limited memory and the latency involved in device/host communication. We describe an implementation of the Low-Rank Incremental SVD which exploits the streaming characteristic of the algorithm to overcome these challenges. We demonstrate the performance of the method, compare it against traditional approaches, and discuss possible application on other memory-constrained platforms.

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MS93

Multifrontal Sparse QR Factorization on a GPU

Sparse direct methods exhibit a mix of regular and irregular computations. Nodes in a multifrontal assembly tree represent the factorization of a dense submatrix, and edges represent the assembly of data from child to parent. We demonstrate a sparse QR multifrontal method in which multiple frontal matrices are simultaneously factorized and assembled on the GPU with a high occupancy rate and streamlined asynchronous data movements to/from the CPU.

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MS93

KokkosArray : Multidimensional Arrays for Manycore Performance-Portability

Performance on manycore devices is dependent data access patterns where different devices (NVIDIA, Intel-Phi, NUMA) require different data access patterns. A performance-portable programming model does not force a false-choice between arrays-of-structures or structures-of-arrays, instead it defines abstractions to transparently adapt data structures to meet device requirements. The KokkosArray library implements this strategy through simple and intuitive multidimensional array abstractions. Usability and performance-portability is demonstrated with proxy-applications for finite element and molecular dynamics codes.

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MS93

Exploiting Trends in Emerging Manycore Processors

Although there is still a lot of uncertainty in the design of future manycore systems, some trends are emerging and are worth targeting for new algorithms and software. In this presentation we talk about strategies that we can use today for designing algorithms and software that will be useful now and in the future. We discuss in particular motivation and strategies for introducing vectorization, threading and latency tolerance techniques.

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MS94

Utility Optimization and Turnpike Properties for Long Term Investments

Turnpike properties show that if utility at large wealth levels are similar to power utility, then the investment strategy converges to the power utility strategy. We study utility optimization problem and turnpike property. We give a new and direct proof by use of PDE approach and the duality method. Our results generalize and improve the previous results. We discuss also the turnpike property for consumption problem. This talk is based on a joint work with H. Zheng.

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MS94

Efficient Exponential Time Differencing Methods for the Valuation of American Options with Multi-State Regime Switching

We propose new exponential time differencing schemes to solve the PDE systems for pricing two assets American option with regime switching. Multistate regime switching for two assets adds significant complexity in the PDE systems due to regime coupling. Different interest rates and volatilities make the problem more challenging. Numerical examples demonstrate the efficiency and reliability of the methods for pricing American options as well Greeks in several regimes.

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MS94

Improved Convergence Order of Binomial Tree Methods for Pricing American Options

Traditional binomial tree for pricing American options has only an accuracy of $O(1/\sqrt{n})$ where n is the number of time-steps. In this talk I will present a control variate technique using capped options to reduce the early exercise errors and to improve the convergence order of the binomial tree. Rigorous proofs of the convergence order are provided and numerical examples are carried out to support the theoretical findings.

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MS94

Implicit-Explicit Time Discretizations for Option Pricing under Jump-Diffusion Models

Partial-integro differential (PIDE) formulations are often used to price options under jump-diffusion models. Their discretizations lead to dense matrices or matrix blocks. With implicit-explicit (IMEX) time discretizations, solutions with these dense matrices can be avoided. Such discretizations lead to an efficient and accurate way to price options.

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MS95

Fluctuating Hydrodynamics Thermostats for Dynamic Studies of Soft Materials Using Implicit-Solvent Coarse-Grained Models

Abstract not available at time of publication.

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MS95

Kinetic Density Functional Theory of Freezing

A theory of freezing of a dense hard sphere gas is presented. Starting with a particle description the revised Enskog theory is chosen as the equation of motion. Using the Chapmann Enskog method, non-local hydrodynamics is derived for the kinetic theory. The over damped limit and the hydrodynamics are analyzed to understand the model as a time dependent density functional theory. The ability of the so derived density functional theory to capture the solid liquid phase transition, the existence of a metastable branch of the liquid phase and the jamming transition is demonstrated. Some numerical results to demonstrate the ability of the hydrodynamic model to capture the solid liquid phase transition are also presented.

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MS95

Locomotion of Helical Bodies in Viscoelastic Fluids

Many microorganisms swim by rotating helical flagella, often propelling themselves through fluids that exhibit both viscous and elastic responses to deformations. We have studied numerically the force-free swimming of a rotating helix in a viscoelastic (Oldroyd-B) fluid. The introduction of viscoelasticity can either enhance or retard the swimming speed depending on the body geometry and the fluid properties. The numerical results show how the small-amplitude theoretical calculations connect smoothly to the large-amplitude experimental measurements.

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MS95

Stochastic Eulerian Lagrangian Methods for Fluid-Structure in Confined Geometry

We study the fluid-structure interactions subject to thermal fluctuations in confined geometries. A stochastic Eulerian Lagrangian method with stochastic force field generation is presented. To validate the methodology, we perform both the pinned particle and particle constrained by the harmonic spring subjected to thermal forces tests. To further demonstrate the applicability of the methodology, we study the mobility and diffusivity of ellipsoids in confined geometry.

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MS96

Vortex Swarms

We investigate the dynamics of N point vortices in the plane, in the limit of large N. We consider *relative equilibria*, which are rigidly rotating lattice-like configurations of vortices. These configurations were observed in several recent experiments [Durkin and Fajans, Phys. Fluids (2000) 12, 289293; Grzybowski *et.al* PRE (2001)64, 011603]. We show that these solutions and their stability are fully characterized via a related *aggregation model* which was recently investigated in the context of biological swarms [Fetecau *et.al.*, Nonlinearity (2011) 2681; Bertozzi *et.al.*, M3AS (2011)]. By utilizing this connection, we give explicit analytic formulae for many of the configurations that have been observed experimentally. These include configurations of vortices of equal strength; the N+1configurations of N vortices of equal strength and one vortex of much higher strength; and more generally, N+K configurations. We also give examples of configurations that have not been studied experimentally, including N+2 configurations where N vortices aggregate inside an ellipse.

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MS96

Spectral Stability Properties of Periodic Traveling Waves in the Sine-Gordon Equation

We study the spectral stability properties of periodic traveling waves in the sine-Gordon equation, including waves of both subluminal and superluminal propagation velocities as well as waves of both librational and rotational types. We prove that only subluminal rotational waves are spectrally stable and establish exponential instability in the other three cases. Our proof corrects a frequently cited one given by Scott. This is joint work with Chris Jones, Robert Marangell, and Ramón Plaza.

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MS96

Wavenumber Selection in the Wake of Fronts

We'll discuss patterns that emerge in the wake of fronts. Examples include spinodal decomposition, chemotaxis, and oscillations in chemistry and biology. We focus on the question of wavenumbers selected in the wake. Main results show existence of fronts and predict wavenumbers in terms of absolute spectra.

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MS97

Projecting Future Climate Based on Model-Observation Consistency in the Past

Forecasting future regional climate is an important societal issue, but challenging. A Bayesian space-time methodology is proposed, which is based on blending different members of an ensemble of regional climate model (RCM) simulations while accounting for the discrepancies between these simulations, under present day conditions, and observational records for the recent past. Results are shown for blended forecasts of 21st century climate based on simulations from the North American Regional Climate Change Assessment Program (NARCCAP).

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MS97

Uncertainty Quantification for Regional Climate Change Projection

Regional climate model (RCM) output can be very-large-to-massive. Several RCMs run for the same period only add to the data size. By modeling the RCM output spatially and statistically, uncertainties can be quantified, however dimension reduction is a practical imperative. We take a fully Bayesian approach involving dimension reduction. That reduces the computation time to on the order of hours. Outputs from the North American Regional Climate Change Assessment Program (NARCCAP) will be analyzed.

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MS97

Inferential Uncertainty Introduced by Biased Or Missing Observations

Large volume of climate data have been collected by satellite remote sensing instruments and ground observations for climate study. However, many such data sets may carry significant intrinsic bias for statistical inference, due to satellite orbit configuration, ground station locations, or missing observations. In this talk, we discuss the effects of such bias in statistical inference and some potential methods to address such issues. This is joint work with Tian Chen and Prof. Elizabeth Stasny

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MS97

Influence of Climate Change on Extreme Weather Events

The increasing frequency of extreme weather events raises the question of to what extent such events can be attributed to human causes. This talk will discuss an approach to these issues based on extreme value theory, incorporated into a Bayesian hierarchical model for combining climate models runs and the observational record. We illustrate the method with examples related to the European heatwave of 2003, the Russian heatwave of 2010, and the Texas/Oklahoma heatwave and drought of 2011. This is joint work with Michael Wehner (Lawrence Berkeley Lab).

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MS98

Phase Transitions in Convex Geometry and Optimization: Geometric Foundations

This is part 2 of the joint work with Martin Lotz.

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MS98

Numerical Homotopy Tracking for Determinantal Representations of Hyperbolic Curves

A smooth curve in the real projective plane is hyperbolic if its ovals are maximally nested. By the Helton-Vinnikov Theorem, any such curve admits a definite symmetric determinantal representation. We compute such representations numerically by tracking a specially designed homotopy in a space of regular real polynomial systems. Giving theoretical complexity bounds for the resulting algorithm is a wide open question. (Joint work with Daniel Plaumann)

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MS98

Phase Transitions in Convex Geometry and Optimization: the Statistical Dimension and Applications

Convex optimization provides a powerful approach to solving a wide range of problems under structural assumptions on the solutions. Examples include solving linear inverse problems or separating signals with mutually incoherent structures. A curious phenomenon arises when studying such problems; as the underlying parameters in the optimization program shift, the convex relaxation can change quickly from success to failure. We reduce the analysis of these phase transitions to a summary parameter, the statistical dimension, associated to the problem. We prove a new concentration of measure phenomenon for some integral geometric invariants, and deduce from this the existence of phase transitions for a wide range of problems; the phase transition being located at the statistical dimension. We furthermore calculate the statistical dimension in concrete problems of interest, and use it to relate previously existing—but seemingly unrelated—approaches to compressed sensing by Donoho and Rudelson & Vershynin. This is joint work with Dennis Ameluxen.

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MS98

How Much does it Cost to Find Eigenvalues of Matrices?

The question of the cost of finding eigenvalues of matrices with respect to different algorithms and a probability distribution on the space of matrices is an open problem. I will discuss homotopy methods studied in the work of Diego Armentano and the Francis shift for the QR algorithm.

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MS99

Radar Imaging through Dispersive Media

In this work we employ microlocal analysis to solve an inverse scattering problem in radar imaging. Our goal is to sense objects of interest embedded in a material that is temporally dispersive and address the problem to improve imaging resolution. We provide with numerical simulations of the inverse algorithm.

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MS99

A Multiscale Approach to Synthetic Aperture Radar in Dispersive Random Media

Abstract not available at time of publication.

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MS99

Is a Curved Flight Path in SAR better than a Straight One?

In the plane, we study the transform Rf of integrating a unknown function f over circles centered at a given curve γ. This is a simplified model of SAR, when the radar is not directed but has other applications, like thermoacoustic tomography, for example. We study the problem of recovering the wave front set WF(f). If the visible singularities of f hit γ once, we show that WF(f) cannot be recovered in, i.e., the artifacts cannot be resolved. If γ is the boundary of a strictly convex domain Ω, we show that this is still true. On the other hand, in the latter case, if f is known a priori to have singularities in a compact set, then we show that one can recover WF(f), and moreover, this can be done in a simple explicit way, using backpropagation for the wave equation.

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MS100

Metastability and Coarse-Graining of Stochastic System

The study of rare events in physical, chemical and biological systems are important and challenging due to the huge span of time scales. Coarse-graining techniques, Markov state models for example, are employed to reduce the degree of freedom of the system, and hence enables simulation and understanding of the system on a long time scale. In this talk, we will introduce a novel construction of Markov state model based on milestoning. We will focus on the analysis of quality of approximation when the original system is metastable. The analysis identifies quantitative criteria which enable automatic identification of metastable sets.

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MS100

Sparse Surrogate Model Construction Via Compressive Sensing for High-Dimensional Complex Models

For complex models with a large number of input parameters, surrogate model construction is challenged by insufficient model simulation data as well as by a prohibitively large number of parameters controlling the surrogate. Bayesian sparse learning approaches are implemented in order to detect sparse-basis expansions that best capture the model outputs. We enhanced the Bayesian compressive sensing approach with adaptive basis growth and with a data-driven, piecewise surrogate construction.

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MS100

An Explicit Cross-Entropy Scheme for Mixtures

The key issue in importance sampling is the choice of the alternative sampling distribution, which is often chosen from the exponential tilt family of the underlying distribution. However, when the problem exhibits certain kind of nonconvexity, it is very likely that a single exponential change of measure will never attain asymptotic optimality and can lead to erroneous estimates. In this paper we introduce a simple iterative scheme with combines the cross-entropy method and the EM algorithm to find an efficient alternative sampling distributions in the form of mixtures. We also study the applications of this scheme to the estimation of rainbow option prices.

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MS100

Uncertainty Quantification in Molecular and Mesoscopic System

We propose a method to quantify the uncertainties in a mesoscopic system based on dissipative particle dynamics (DPD). This method employs l_1 minimization to recover the coefficients in generalized polynomial chaos (gPC) expansion given prior knowledge that the coefficients are "sparse". We implement this method to study hydrodynamic properties (viscosity, diffusivity) of DPD fluid. As DPD simulation is costly, this method exploits information from the limited data, hence it is efficient.

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MS101

Hybrid (adjoint/ensemble) Uncertainty Quantification Methods for Data Assimilation and Adaptive Observation of Environmental Plumes

Abstract not available at time of publication.

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MS101

How Well Does Polynomial Chaos Model Chaos?

We explore the effectiveness of polynomial approximations for modeling time averaged statistics from a chaotic dynamical system as a function of the system parameters in an attempt to answer, how well does polynomial chaos model chaos?

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MS101

Optimal Maps for Data Assimilation in Nonlinear Chaotic Systems

We present a new optimal-map approach to sequential data assimilation, i.e. nonlinear filtering and smoothing. The main idea is to push forward a fixed reference measure to each assimilated state distribution. Our algorithm inherently avoids issues of sample impoverishment, since it explicitly represents the posterior as the pushforward of a reference measure. We demonstrate the efficiency and accuracy of the map approach via data assimilation in several canonical dynamical models, e.g., Lorenz-63 and Lorenz-96 systems.

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MS101

Continuum Heat Transfer Constitutive Laws with Quantified Uncertainty Extracted from Atomistic Simulations Using Bayesian Inference

Unclosed partial differential equations (PDE) arise owing to their derivation from coarse-grained small-scale processes. Their closure is a ubiquitous problem in computational science. We propose a solution to this problem using Bayesian inference to estimate constitutive relationships based on samples of the underlying small-scale processes. Uncertainty quantification is required to propagate the uncertain closure models through the continuum solution. Both parametric and non-parametric results are presented for continuum heat conduction informed by atomistic data.

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MS102

Automating and Stabilizing the Discrete Empirical Interpolation Method for Nonlinear Model Reduction

The Discrete Empirical Interpolation Method (DEIM) is a technique for model reduction of nonlinear dynamical systems. I will describe a methodology for automatically applying the method given only code for evaluating the full model. Although DEIM has been effective on some very difficult problems, it can under certain conditions introduce instabilities in the reduced model. I will present a problem that has proved helpful in developing a method for stabilizing DEIM reduced models.

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MS102

An Exact Solution Formula for the Kadomtsev-Petviashvili Equation

In general, nonlinear partial differential equations (NPDEs) do not yield exact solutions and are solved using numerical methods. Our goal is to use a systematic method to obtain a formula for certain exact solutions to the Kadomtsev-Petviashvili equation, a NPDE in two spatial and one temporal variable. The formula is expressed in terms of a constant matrix quadruplet and matrix exponentials.

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MS102

Resonant Instability and Nonlinear Wave Interactions in Electrically Forced Jets

We investigate the problem of linear temporal instability of the modes that satisfy the dyad resonance conditions and the associated nonlinear wave interactions in jets driven by either a constant or a variable external electric field. A mathematical model, which is developed and used for the temporally growing modes with resonance and their nonlinear wave interactions in electrically driven jet flows, leads to equations for the unknown amplitudes of such waves that are slowly modulated.

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MS102

A Model of Photoreceptor Degeneration in Zebrafish Via a Cone Mutation

Photoreceptors are responsible for vision, and their degeneration, often caused by mutations of the rods or cones, is one of the leading causes of blindness. Zebrafish, with their cones more numerous in comparison to the rods than in humans, are important to study for cone mutations that may lead to blindness in humans. We propose a mathematical model of photoreceptor interactions of the Zebrafish with a cone mutation, analyze the long term dynamics of the system, and compare results with recent biological investigations and findings.

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MS103

Special Function Integrals by the Method of Brackets

Originally developed by Gonzalez and Moll in the study of Feynmann diagrams, the "method of brackets" is a heuristic method for symbolic definite integration. A Sage implementation and testing against a table of integrals has shown that this method can be very effective for definite integration problems involving many special functions. Experimentation with integrals involving such special functions as Bessel functions and orthogonal polynomials has led to improvements of the method.

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MS103

Toward an On-Demand Data Service for Special Functions

Tables of function values, formerly essential for scientific computing, have been replaced with software. Generally available software covers vastly greater argument ranges but accuracy is not uniform. Old tables were painstakingly checked to avoid this defect. Using interval techniques, NIST and the University of Antwerp are developing an online tables-on-demand capability. It returns uniformly accurate numerical values for specified arguments and precision, and optionally a digit-by-digit comparison to values entered from another source.

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MS103

Numerical Methods for Special Functions

For the numerical evaluation of special functions we mention the basic tools: series expansions, recursions, and quadrature. We give examples on how to use tools in recently developed software in our project, in particular how to handle highly oscillating integrals in the complex plain. We explain how to select suitable quadrature rules, and why the simple trapezoidal rule may be very efficient for a certain class of integrals that represent special functions.

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MS103

Stieltjes-Wigert Polynomials and the q-Airy Function

Asymptotic formulas are derived for the Stieltjes-Wigert polynomials $S_n(z;q)$ in the complex plane, with the $q-$Airy function $A_q(z)$ being used as the approximant. One formula holds in any disc centered at the origin, and the other holds outside any smaller disc centered at the origin; the two regions together cover the whole plane. For $x > 1/4$, a limiting relation is also established between the $q-$Airy function $A_q(x)$ and the ordinary Airy function $\mathrm{Ai}(x)$ as $q \to 1$.

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MS104

Nonlinear Response of Bio-Polymers Subject to Stretching Flow with Thermal Noise

The dynamics of elastic filaments subject to hydrodynamic forces exhibits complex nonlinear dynamics in the neighborhood of stagnation points in the flow. Here, the motion of a single inextensible bio-polymer with anisotropic friction tensor subjected to a stretching flow is modeled with stochastic differential equations as well as dissipative particle dynamics simulations. Our results show that the negative tension induces a stretch-coil transition beyond a critical value, where the noise is amplificated due to the interaction of thermal noise and nonlinear effects.

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MS104

Increased Accuracy of Immersed Boundary Methods Using Fourier Approximations of Delta Functions

In immersed boundary methods, the fluid and structure communicate through smoothed approximate delta functions with small spatial support. We take a different approach and construct highly accurate approximations to the delta function directly in Fourier space. This method leads to high-order accuracy away from the boundary and significantly smaller errors near the boundary. We present accuracy tests and simulation results from an application in cell biology in which large errors in the traditional IB method produce unphysical results.

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MS104

The Moment of Fluid Interface Reconstruction with Filaments: Increasing Sub-Gridcell Resolution

The Moment of Fluid (MOF) method is a highly accurate technique for reconstructing material interface(s) that exactly captures material volume and minimizes error in the centroid(s). The method has been extended to perform reconstruction for an arbitrary number of materials in a cell. In the two material case, the introduction of a fictitious third material can allow for the resolution of thin, unresolved structures (filaments) or regions of high curvature, detected via error in the centroid(s).

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MS104

Variational Implicit Solvation of Biomolecules

Recent years have seen the initial success of variational implicit-solvent models (VISM), implemented by the level-set method, for biomolecular interactions. Central in VISM is an effective free-energy functional of all possible solute-solvent interfaces, coupling together the solute surface energy, solute-solvent van der Waals interactions, and electrostatic contributions. The level-set relaxation of such a functional determines numerically biomolecular equilibrium conformations and minimum free energies. Comparisons with experiments and molecular dynamics simulations demonstrate that the level-set VISM can capture the hydrophobic hydration, dry-wet fluctuation, and many other important solvation properties. This talk begins with a review of the level-set VISM and continues to present new developments around the VISM. These include: (1) the coupling of solute molecular mechanical interactions in the VISM; (2) the effective dielectric boundary forces; and (3) the solvent fluid fluctuations. Mathematical theory and numerical methods are discussed, and applications are presented. This is joint work with J. Andrew McCammon, Li-Tien Cheng, Joachim Dzubiella, Jianwei Che, Zhongming Wang, Shenggao Zhou, and many others.

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MS106

A Difference of Convex Method to Select Point Correspondences for Image Registration

This talk will present an algorithm for image registration that is based on minimizing a difference of convex model. The method selects point correspondences between images by identifying pairs of points that have similar local features and are also consistent with a given deformation model. We consider both affine transformations and more general smooth displacement fields. The unknown deformation is reconstructed from estimated displacements at relatively few points.

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MS106

Compressive Video Using Single Pixel Cameras

”Single-pixel cameras” are a new modality for image acquisition using compressive measurements. In contrast to conventional imaging, which relies on arrays of many photodetectors, single picture cameras obtain high resolution images using only a single detector. This is accomplished using a ”coded aperture,” which compresses global image information into each measurement rather than observing one pixel at a time. In this talk, we discuss the challenges of applying these new compressive imaging tools to video acquisition. Compressive video poses many challenges that imaging does not. We are no longer imaging a static scene, but rather we must explicitly model the motion of objects and exploit correlations between adjacent frames. Furthermore, real-time reconstruction of video from compressive measurements requires the use of sophisticated numerical algorithms and parallel hardware implementations.

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MS106

Fast Algorithms for Adaptive Temporal Compres-

sion in Video Data

Video data is redundant both spatially and temporally, where the temporal redundancy is closely related to the motion changes between successive frames. Recent video compression often relies on a fixed and relatively low temporal sampling rate. In this talk, we investigate adaptive video compression by combining the idea of patch based polynomial interpolation with learning. A new technique is proposed to detect real-time motion changes based on a small amount of previously compressed frames. Numerical experiment on real data shows this information can help predict the compression rate adaptively.

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MS106

Alternating Direction Approximate Newton Method for Partially Parallel Imaging

It has been shown that the Bregman operator splitting algorithm with variable stepsize (BOSVS) is globally convergent and asymptotically efficient for magnetic resonance image reconstruction. However, the convergence of the algorithm relies on the choice of a number of parameters. This paper propose a new algorithm, alternating direction approximate newton (ADAN) method for solving convex and possibly nonsmooth optimization problem. The global convergence of this algorithm will be established. Experimental results and computational analysis are given using partially parallel magnetic resonance image reconstruction. We show that ADAN yields comparable performance to BOSVS, but it is simpler to implement and employs fewer parameters.

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MS107

Diffuse Optical Cortical Mapping Using the Bem++ Boundary Element Library

Diffuse Optical Cortical Mapping (DOCM) is a method of mapping the functional activation in the brain by detecting its effect on optical absorption in the near-infrared. It is commonly achieved using a dense array of sources and detectors and a volume model of optical photon propogation. This is a highly underdetermined inverse problem so is usually postprocessed to project the reconstruction onto the cortical surface. In our method we use a BEM surface formulation. We discuss the implementation of this using the public-domain BEM++ library developed by the authors.

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MS107

Accelerated Statistical Image Reconstruction Methods in X-Ray Computed Tomography (ct): Advances in Algorithm Developments and Clinical Practices

Abstract not available at time of publication.

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MS107

Tensor Framelet based Novel Reconstruction Methods for Better and Faster CT Imaging

This talk will attempt to address the following two questions: (Q1) ”Better” Imaging: provided with the same CT sinogram, can we develop new reconstruction method to further improve the state-of-art image quality? (Q2) ”Faster” Imaging: under the similar image quality standard, can we fully explore the new method for faster CT imaging, in terms of (1) faster undersampled 3D/4D data acquisition, and (2) faster image reconstruction speed that is clinically usable? A key is (A1) the use of L1-type iterative reconstruction method based on tensor framelet (TF). Another critical component for developing fast clinically-usable reconstruction is (A2) the rapid parallel algorithm for computing X-ray transform and its adjoint (O(1) per

parallel thread). Then we will move on to (A3) the super-resolution technique for spiral CT to enhance axial image resolution and reduce axial partial volume artifacts, (A4) fused Analytical and Iterative Reconstruction (AIR) method as a general framework to fuse analytical reconstruction method and iterative method, and (A5) adaptive TF Technique for 4D imaging.

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MS108

An Overview of Web-Based CO2 Subsurface Flow Modeling

Accumulation of greenhouse gases from the combustion of fossil fuels has led to an increase in solar radiation trapped between the earth and atmosphere, which may lead to catastrophic changes in global weather conditions. With CO2 being the most abundant greenhouse gas, efforts are underway to reduce the level of CO2 entering the atmosphere through sequestration into deep rock formations. Through numerical simulation, one can predict if CO2 can remain permanently sequestered in such formations.

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MS108

Numerical Poroelastic Pressure Diffusion Simulation in CO2 Sequestration

CO2 sequestration in underground aquifers shows significant potential in reducing greenhouse gas emissions. However, rock fractures, formed during injection, may release toxic species into the water table and release CO2 back into the atmosphere. A pore pressure diffusion module has been implemented into a reactive transport modeling application to simulate effects of fluid gain stresses on rocks caused by CO2-rich water injection. Results are compared with bottom-hole pressure data from an Oligocene Frio Formation observation well.

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MS108

Using the Helgeson-Kirkham-Flowers Model to Study Reservoir Temperature Evolution During CO2 Injection

A one-dimensional numerical heat transfer module has been implemented into a reactive transport modeling application to study temperature effects resulting from CO2-rich water injection into sedimentary basins. Thermophysical properties of charged aqueous solutes are computed using the Helgeson-Kirkham-Flowers model, coupled with an advection-diffusion heat transport model, to determine spatial and temporal temperature profiles during injection. Results show an increase in temperature, caused by the arrival of the CO2-rich injectant, which is in agreement with well data.

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MS108

A Study of High-Performance Computing Tools in Simulating Carbon Dioxide Geologic Sequestration Scenarios

In Carbon Sequestration, codes that simulate water-rock interaction and reactive transport sequentially solve mass balance equations for each control volume representing a lithology containing charged aqueous solutes. This is not well suited for execution on many-core computers. We present the theory and implementation of a numerical scheme whereby solute concentrations in all control volumes are solved simultaneously by constructing a large block-banded matrix. These matrices are factored with SuperLU_DIST (Berkeley Laboratory). Performance metrics are evaluated.

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MS109

Best Location of Actuators for the Stabilization of the Navier-Stokes Equations

We study the boundary feedback stabilization, about an unstable stationary solution, of a two dimensional fluid flow described by the Navier-Stokes equations, around a disk in a channel. The control is a Dirichlet boundary control localized on the boundary of the disk in two slots of a fixed aperture. A feedback control law is determined by stabilizing the linearized Navier-Stokes equations about the unstable stationary solution. We determine the best control zone, that is the one minimizing the control norm of the closed loop linear system, in the case of the worst perturbation in the inflow boundary condition. This approach allows us to improve the efficiency of the feedback control laws when they are applied to the nonlinear system. It will be confirmed by several numerical simulations. This is a joint work with J.-M. Buchot and M. Fournié from the Toulouse Mathematical Institute, and C. Airiau and J. Weller from the Institute of Fluid Mechanics in Toulouse.

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MS109

Balanced POD: Approximation Capability and Potential for Nonlinear Model Reduction

The excellent data approximation capability of proper orthogonal decomposition (POD) is well known and is a major reason why POD is widely used for nonlinear model reduction. Balanced POD is a recent data-based model reduction algorithm for linear systems of ordinary and partial differential equations. We present new results showing that balanced POD can produce excellent approximations of two separate data sets, and we discuss the potential of balanced POD for nonlinear model reduction.

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MS109

An Adjoint-Based Approach for the Understanding of Flapping Wings

Adjoint-based methods show great potential in flow control and optimization of complex problems. When unsteady flapping motion and deformation is considered, however, the traditional adjoint-based approach used commonly in airfoil design falls short of the definition of sensitivity at the unsteady moving/morphing boundary. Using the idea from non-cylindrical shape analysis, we are able to derive an adjoint-based analysis in a rigorous and simple manner for the optimization of moving/morphing objects such as flapping wings.

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MS109

Malliavin Calculus for Stochastic Point Vortex and Lagrangian Models

Abstract not available at time of publication.

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MS110

Strategies and Challenges of Reproducibility in Global Climate Modeling

The standards for reproducibility for climate simulation are necessarily strict, given the level of attention from the broad scientific community, economic and political stakeholders, and the general public. A brief summary of several recent global Earth system simulation efforts are presented, with a focus on the challenges and strategies to attain reproducibility as these models are extended to include additional complexity and detail.

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MS110

Reproducibility and Repeatability: A Roadmap for the Computational Scientist

The ubiquitous presence of parallelism at all levels of computing is forcing difficult choices between reproducible, repeatable computing and performance. This concern is emerging within the broader concerns of verification and validation, creating both new issues and, perhaps, new opportunities. In this presentation, we give a broad overview of the issues that are of particular interest to computational scientists.

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MS110

Efficient Reproducible Floating Point Reduction Operations on Large Scale Systems

On large-scale systems, with highly dynamic scheduling to improve load balance, users should no longer expect to obtain identical results from run-to-run for floating point operations like summation. We propose a technique to obtain reproducibility for the global sum with no extra communication. Input numbers are decomposed into vectors of floating-point numbers using pre-determined boundaries. All processors can perform their local computations independently. The final result is produced by using a special reduction operator: the maximum of boundaries followed by the sum of corresponding components. This technique performs well at very large scale where communication time dominates computing time, so that the running time of the reproducible sum is almost equal to the running time of the standard sum. This technique can be applied to other operations for example the dot product and the matrix-matrix multiplication, as well as to other higher level driver routines such as trsv, trsm.

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MS111

H-to-P Efficiently: A Progress Report on High-Order Fem on Manifolds with Applications in Electrophysiology

In this talk, we describe the numerical discretisation of an embedded two-dimensional manifold using high-order spectral/hp elements. Such methods provide an exponential

reduction of the error with increasing polynomial order, while retaining geometric flexibility of the domain. Embedded manifolds are considered a valid approximation for many scientific problems ranging from the shallow water equations to geophysics. We describe and validate our discretisation technique and provide a motivation of its application to modeling electrical propagation on the surface of the human left atrium.

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MS111

High Order Asymptotic Preserving Methods for Discrete-velocity Kinetic Equations

A family of high order asymptotic preserving schemes are proposed for several kinetic models with discrete velocity. The methods are based on the micro-macro decomposition of the equations, and they combine discontinuous Galerkin spatial discretizations and IMEX temporal discretizations. Both theoretical and numerical studies are carried out to demonstrate the performance of the methods.

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MS111

On the Bound of DG and Central DG Operators for Linear Hyperbolic Problems

It is observed that central discontinuous Galerkin (DG) methods often admit larger time steps than DG methods. To understand this, we show that for the linear advection equation, the norm of the derivative operator from the upwind DG method grows quadratically with the order of the method, while that of the central DG methods grow linearly. Our estimates are validated numerically, and they can be extended to higher dimensions and linear hyperbolic systems.

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MS111

H-to-P Efficiently: A Progress Report on Hdg in 3D

In this talk, we assess the performance of the Hybridized Discontinuous Galerkin (HDG) method applied to three dimensional elliptic operators by comparing it to the statically condensed continuous Galerkin (CG) method. Performance comparison will include such items as set-up costs, rank, bandwidth and solve times of the global trace system and the parallelization efficiency for the two methods.

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MS111

Error Estimates of RKDG Methods for the Vlasov-Maxwell System

In this talk, error analysis is established for Runge-Kutta discontinuous Galerkin (RKDG) methods to solve the Vlasov-Maxwell system. This nonlinear hyperbolic system describes the time evolution of collisionless plasma particles of a single species under the self-consistent electromagnetic field, and it models many phenomena in both laboratory and astrophysical plasmas. The methods involve a third order TVD Runge-Kutta discretization in time and upwind discontinuous Galerkin discretizations of arbitrary order in phase domain. With the assumption that the exact solution has sufficient regularity, the L^2 errors of the particle number density function as well as electric and magnetic fields at any given time T are obtained under certain CFL condition. The analysis can be extended to RKDG methods with other numerical fluxes and to RKDG methods solving relativistic Vlasov-Maxwell equations.

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MS112

The Matrix Unwinding Function

We introduce a new primary matrix function, called the matrix unwinding function, that is instrumental in deriving correct identities involving logarithms. We show that it facilitates the understanding of other complex multivalued matrix functions including inverse trigonometric functions. We also use it to study the matrix sign function. Finally, we give a numerical scheme for computing the matrix unwinding function and show how it can be used to compute the matrix exponential using the idea of argument reduction.

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MS112

Block Krylov Subspace Methods and a Preconditioning Approach for the Matrix Exponential Action

In the first part of the talk a brief introduction to the minisession topics will be given. In the second part of the talk a preconditioned iterative scheme for computing actions of the matrix exponential will be presented. The scheme is based on an acceleration of the exponential Richardson iteration, recently considered in [M.A.Botchev, V.Grimm, M.Hochbruck, Residual, restarting and Richardson iteration for the matrix exponential, SISC, 2013]. This talk is partly based on a joint work with I. Oseledets and E. Tyrtyshnikov, Institute of Numerical Mathematics, RAS, Moscow.

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MS112

Matrix Functions and Their Krylov Approximations for Wave Propagation in Unbounded Domains

Solution of wave problems in unbounded domains requires computation of the exponential of the spatial PDE operator with continuous spectrum. To avoid spurious resonances, the reduced order model should preserve spectral continuity of the original problem. The authors introduce so-called stability-corrected time-domain exponential (SCTDE) of dumped discretization matrix possessing this conservation property. However, convergence of the Krylov subspace approximation of the SCTDE matrix function decelerates due to appearance of the square root singularity. We improve convergence by employing extended Krylov subspace.

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MS112

Transient Electromagnetic Simulation in Geophysical Exploration

In recent work we explored how the initial value problem for the quasi-static Maxwell's equations arising in transient electromagnetic modeling (TEM) can be solved efficiently in the frequency domain by solving a small projected model for each relevant frequency using simple shift-and-invert type Krylov subspace projection much in the style of classical model order reduction for linear time-invariant control problems. In this work we present more advanced rational Krylov subspace methods employing more elaborate pole selection techniques. We also compare this frequency domain approach with solving the problem in the time domain using the same rational Krylov subspace methods to approximate the action of the matrix exponential.

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MS113

Stochastic Nucleation in Biology

Stochastic Nucleation in Biology The binding of individual components to form composite structures is a ubiquitous phenomenon within the sciences. Within heterogeneous nucleation, clusters form around exogenous structures such as impurities or boundaries, while in homogeneous nucleation identical particles cluster upon direct contact. Particle nucleation and growth have been extensively studied, often assuming infinitely large numbers of

monomers and unbounded cluster sizes. These assumptions led to mass-action, mean field descriptions such as the well known Becker Doering equations. In cellular biology, however, nucleation events often take place in confined spaces, with a finite number of components, so that discrete and stochastic effects must be included. In this talk we examine finite sized homogeneous nucleation by considering a fully stochastic master equation, solved via Monte-Carlo simulations and via analytical insight. We find striking differences between the mean cluster sizes obtained from our discrete, stochastic treatment and those predicted by mean field treatments. We also consider heterogeneous nucleation stochastic treatments, first passage time results and possible applications to prion unfolding and clustering dynamics.

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MS113

Introducing Stochasticity into a Continuum Model for Transcription

Experimental data indicates that polymerase motion on DNA exhibits abrupt, frequent pausing. Assuming a certain density-velocity relationship incorporating a nonuniform distribution of pauses, a nonlinear conservation law model with discontinuous velocity is proposed and shown to be the limit of a mean occupancy ODE system model. Discontinuous Galerkin simulations and convergence results are given. We attempt to quantify the affects that both pause location and mean duration time have on the overall production of mRNA.

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MS113

From Asymmetric Exclusion Processes to Protein Synthesis

Asymmetric exclusion processes, with periodic or open boundaries, have been studied extensively in the mathematics and statistical physics communities, as paradigmatic models for stochastic particle transport far from equilibrium. Though significant progress was made only recently, the original model was actually introduced decades ago to model protein synthesis. In this talk, I will describe recent efforts to develop a comprehensive theory for protein synthesis, building on asymmetric exclusion processes with extended objects, modeling ribosomes covering multiple codons. We discuss the effects of local hopping rates and ribosome size on density profiles and particle currents. The latter translate directly into synthesis rates for the corresponding protein. Some intriguing results for real genes will be presented. high-level commands.

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MS113

A Discontinuous Method for Analyzing and Modeling Delay Due to Pauses During Transcription

A Discontinuous Galerkin Finite Element Method is used for the simulation of a nonlinear conservation law modeling traffic flow with several traffic lights. This is used to model the motion of polymerases on ribosomal RNA during the process of transrciption. Physically relevant pauses along the rrn operon are incorporated into the model. Using the DG solution, the average delay experienced by a polymerase due to the pauses is estimated.

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MS114

Property Testing in the Real Number Model

Property testing asks for checking with a randomized algorithm whether a given piece of data represents with high probability a certain kind of object. In the talk we consider real function value tables as data and want to check in how far they represent certain low degree polynomials over the real numbers. Our computational model is the real number Turing machine introduced by Blum, Shub, and Smale. Such questions are central in relation to obtaining so-called probabilistically checkable proofs for complexity classes like NP over the reals. This is ongoing joint work with Martijn Baartse.

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MS114

Faster Real-Solving for Random Sparse Polynomial

Systems

Any set, A, of $n + k$ points in $\mathbf{R}^n$ determines a family of polynomials F_A with exponent vectors corresponding to the points of A. We describe an efficient polyhedral method to compute the topology of the real zero set of most f in F_A. The regions defining "most" depend on a refinement of the tropical discriminant. This theory also extends to polynomial systems, but the data structures become more subtle.

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MS114

A Concrete Approach to Hermitian Determinantal Representations

If a Hermitian matrix of linear forms is positive definite at some point, then its determinant is a hyperbolic hypersurface. In 2007, Helton and Vinnikov proved a converse in three variables, namely that every hyperbolic plane curve has a definite Hermitian determinantal representation. In this talk I will discuss a concrete proof of this statement and a method for computing these determinantal representations in practice. This involves relating the definiteness of a matrix to the real topology of its minors and extending a classical construction of Dixon from 1902. This is joint work with Daniel Plaumann, Rainer Sinn, and David Speyer.

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MS114

Computing Regularity from Singularity

In this talk we show how to compute a regular system from a singular polynomial system. For that we defined two operations of defation and of kerneling. Deflation replaces a function by the components of its gradient and kerneling adds the components of a certain Schur complenent when some criteria are satisfied. We explain how performed exact computation from certified numerical tests. This work is done in collaboration with Marc Giusti.

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MS115

Ultrasound Modulated Optical Tomography

Abstract not available at time of publication.

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MS115

Recent Advancement in Photoacoustic Tomography Iterative Image Reconstruction

Photoacoustic computed tomography (PACT) is an emerging soft-tissue imaging modality that has great potential for a wide range of preclinical and clinical imaging applications. In this talk, we review our recent advancements in practical image reconstruction approaches for PACT. Such advancements include physics-based models of the measurement process and associated inversion methods for reconstructing images from limited data sets in acoustically heterogeneous media.

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MS115

Quantitative Photoacoustics Using Transport and Diffusion Models

Abstract not available at time of publication.

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MS115

Gradient-based Bound-constrained Split Bregman Method (GBSB) for Large-scale Quantitative Photoacoustic Tomography

We aim at solving large-scale 3D Quantitative Photoacoustic Tomography (QPAT), e.g., to recover both absorption map and scattering map in the setting of multi-source QPAT. QPAT is formulated as a bound-constrained nonlinear minimization problem with the solution regularized by TV norm, and then the development of the solution algorithm is based on the Split Bregman method, namely, GBSB, gradient-based bound-constrained split Bregman method. The proposed GBSB algorithm can be easily extended for multi-wavelength QPAT and RTE based QPAT.

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MS116

Interannual Variability and Memory Reemergence of North Pacific Sea Ice in Comprehensive Climate Models

We apply nonlinear Laplacian spectral analysis (a manifold generalization of PCA) to extract joint spatiotemporal patterns of variability of sea ice, oceanic, and atmospheric variables from comprehensive climate models. We use the recovered modes to study intraseasonal to interannual variability, including year-to-year memory reemergence, of Arctic sea ice, which is a key component of the global climate. The question of constructing empirical distance metrics for high-dimensional multivariate data is addressed.

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MS116

Zwanzig-Type PDF Equations and Exponential Integrators for Functionals of the Solution to Nonlinear SPDEs with High-Dimensional Parametric Uncertainty

The determination of the statistical properties of the solution to a system of stochastic differential equations (SDEs) is a problem of major interest in many areas of science. Even with recent theoretical and computational advancements, no broadly applicable technique has yet been developed for dealing with the challenging problems of high dimensionality, possible discontinuities in parametric space and random frequencies. Among different uncertainty quantification approaches, methods that model the probability density function (PDF) of the state variables via deterministic equations have proved to be effective in predicting the statistical properties of random dynamical systems. In this talk we present recent developments on PDF methods, at both theoretical and numerical levels, addressing the question of dimensionality of the solution to SDEs. In particular, we introduce a new projection operator technique of Mori-Zwanzig type and a new effective exponential integrator method based on Kubo's generalized cumulants that allow us to determine closed (exact) evolution equations for the PDF of goal-oriented functionals of the solution to SDEs with high-dimensional parametric uncertainty. Numerical applications are presented for nonlinear oscillators driven by random noise, stochastic advection-reaction and Burgers equations.

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MS116

The Wick Approximation of Elliptic Problems with Lognormal Random Coefficients

We discuss the approximation of elliptic problems with log-normal random coefficients using the Wick product and the Mikulevicius-Rozovskii formula. The main idea is that the multiplication between the log-normal coefficient and the gradient can be regarded as a Taylor-like expansion in terms of the Wick product. We focus on the difference between the classical model and the Wick-type model with respect to the standard deviation of the underlying Gaussian random process.

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MS116

PDF Method for Power Generation Systems

Understanding the mesoscopic behavior of dynamical systems described by Langevin equations with colored noise is a fundamental challenge in variety of fields. We propose a new approach to derive closed-form equations for joint and marginal probability density functions (PDFs) of state variables. This approach is based on a so-called Large-Eddy-Diffusivity (LED) closure and can be used for modeling a wide class of non-Markovian processes described by the noise with arbitrary correlation function.

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MS117

Stability Issues in the Theory of Complete Fluid Systems

We discuss multi-scale singular limits for compressible viscous and rotating fluids in the regime of low Mach and Rossby numbers and high Reynolds number. We work in the framework of weak solutions for the primitive system and classical solutions for the target system - here identified as $2D$-incompressible Euler flow. The results are based on careful estimates independent of the scaling parameters and analysis of the associated oscillatory integrals arising in the study of the Poincare waves.

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MS117

Incompressible Limits of Fluids Excited by Moving Boundaries

We consider the motion of a viscous compressible fluid confined to a physical space with a time dependent kinematic boundary. We suppose that the characteristic speed of the fluid is dominated by the speed of sound and perform the low Mach number limit in the framework of weak solutions. The standard incompressible Navier-Stokes system is identified as the target problem.

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MS117

Regularity Problems Related to Brenner-Navier-Stokes Equations

Regularity problems related to Brenner's model of Navier-Stokes equations are investigated. In two dimensional case we give the existence of global regular solution to the initial-boundary value problem. In general case we give a blowup criterion for the regular soltion in terms of upper bound of the density.

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MS117

Relative Entropy Applied to the Study of Stability of Shocks for Conservation Laws, and Application to Asymptotic Analysis

The relative entropy method is a powerful tool for the study of conservation laws. It provides, for example, the weak/strong uniqueness principle, and has been used in different context for the study of asymptotic limits. Up to now, the method was restricted to the comparison to Lipschitz solutions. This is because the method is based on the strong stability in L^2 of such solutions. Shocks are known to not be strongly L^2 stable. We have showed, however that their profiles are strongly L^2 stable up to a drift. We will discuss our recent development of the theory together with applications to the study of asymptotic limits.

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MS118

Fast Integral Equation Method for Maxwell's Equations in Layered Media

In this talk, Maxwell's equations in layered media is studied with a integral equation method. First, a numerical method for calculating the layered media Green's function will be derived using transfer/scattering matrix and Sommerfeld-type integral. Then, a parallel fast algorithm for the layered media integral operator will be presented with the semi fast multipole method for the Bessel function based on the local-expansion.

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MS118

High-order Nystrom Discretization of Boundary Integral Equations in the Plane

Boundary integral equations and Nystrom discretization provide a powerful tool for the solution of Laplace and Helmholtz boundary value problems. The talk describes and compares four different high order techniques for producing very accurate Nystrom discretizations (due to Kapur-Rokhlin, Alpert, Kress, and Kolm-Rokhlin). We compare the numerical performance and discuss practical issues (flexibility, ease of implementation, compatibility with fast summation techniques, etc). Applications to solving 3D scattering problems involving axisymmetric scatterers will be shown.

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MS118

Spectral Deferred Correction Methods for Two-Dimensional Vesicle Suspensions

A boundary integral equation method for simulating inextensible vesicles in 2D viscous fluid is presented. By using spectral deferred correction methods, we introduce an adaptive time stepping strategy. This strategy allows us to better control numerical errors.

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MS118

Isogoemetric Boundary Element Methods on Smooth Domains

Isogeometric analysis has emerged as a framework for integrating computational geometry and finite element methods by adopting interpolation functions widely used in computational geometry as finite element basis functions. In this work, we show that isogeometric analysis is extremely beneficial for boundary element methods: Singularities of certain boundary integral operators are weaker, collocation techniques can be used for hypersingular boundary integral equations, and formulations leading to system matrices with mesh-independent condition numbers can be introduced.

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MS119

Saddle Points, Special Functions and Electromagnetic Pulse Propagation

The angular spectrum representation is a mathematical technique used to describe electromagnetic pulse propagation in homogeneous material. It represents the propagated field as a superposition of homogeneous or inhomogeneous plane waves. As such, saddle point methods have proven useful in the analysis of these wave fields. This talk will review how saddle point methods have been applied to linearly-polarized plane-wave pulses through causal material, and end with consideration of extending these methods to electromagnetic beam propagation.

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MS119

Existence and Uniqueness of Tronquee Solutions of the Third and Fourth Painleve Equations

It is well-known that the first and second Painleve equations admit solutions characterized by divergent asymptotic expansions near infinity in specified sectors of the complex plane. Such solutions are pole-free in these sectors and called tronquee solutions by Boutroux. In this talk, we show that similar solutions exist for the third and fourth equations as well.

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MS119

Some New Techniques in the Approximation of Special Functions

We present some new methods to approximate special functions, one for integrals and one for solutions of differential equations. For integrals we study convergent expansions of integrals derived from expansions of the integrands at non-standard points, including multi-point Taylor expansions. Among the methods for differential equations we investigate modifications of Olver's asymptotic method. We give several examples of which some have been included in the recently published NIST Handbook of Mathematical Functions.

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MS119

The Wright Function and Fractional Diffusion Problems

The Wright function and a number of other related functions play a role in various applications of fractional calculus. In the recent years, intensive research has addressed analysis, modeling, and numerical treatment of *fractional* partial differential equations, e.g., fractional diffusion equations. These may better describe anomalous diffusion problems, providing an explanation to many phenomena. On the one hand, the fractional differential operators, being nonlocal in nature, can take into account delay in time and nonlocality in space. On the other hand, they call for new numerical methods. In this talk, we will present some new schemes, such as higher-odrder ADI methods, and show the usefulness of Wright's functions.

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MS120

Eulerian Methods for Schrodinger Equations in the Semi-Classical Regime

We discuss Eulerian approaches to compute semi-classical solutions of the Schrödinger equations including the Eulerian Gaussian beam method and a recently developed method which incorporating short-time WKBJ propagators into Huygen's principle. These Eulerian are shown to be computationally very efficient and can yield accurate semi-classical solutions even at caustics.

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MS120

A Uniformly Second Order Fast Sweeping Method for Eiknoal Equations

This talk is to introduce a simple and effective second order method for eikonal equations. The method is based on a combination of a "superconvergence" phenomenon of monotone upwind schemes for eiknoal equations combined and a local linear DG formulation. By freezing the information of gradient which is precomputed by monotone upwind schemes, a simple local updating formula for the cell average can be obtained. This local solver is incorporated into an iterative method to get a uniformly second order method for the eikonal equations. Numerical examples are presented to demonstrate its efficiency.

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MS120

High-Order Factorization Based High-Order Hybrid Fast Sweeping Methods

The solution for the eikonal equation with a point-source condition has an upwind singularity at the source point as the eikonal solution behaves like a distance function at and near the source. As such, the eikonal function is not differentiable at the source so that all formally high-order numerical schemes for the eikonal equation yield first-order convergence and relatively large errors. Therefore, it is a long standing challenge in computational geometrical optics how to compute a uniformly high-order accurate solution for the point-source eikonal equation in a global domain. In this paper, we propose high-order factorization based high-order hybrid fast sweeping methods for point-source eikonal equations to compute just such solutions.

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MS120

Energy Conserving Local Discontinuous Galerkin Methods for the Wave Propagation Problems

Wave propagation problems arise in a wide range of applications. The energy conserving property is one of the guiding principles for numerical algorithms, in order to minimize the phase or shape errors after long time integration. In this presentation, we develop and analyze a local discontinuous Galerkin (LDG) method for solving the wave equation. We prove optimal error estimates and the energy conserving property for the semi-discrete formulation. The analysis is extended to the fully discrete LDG scheme, with the energy conserving high order time discretization. Numerical experiments have been provided to demonstrate the optimal rates of convergence.

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MS121

Computing Multiple Solutions of Nonlinear ODEs with Chebfun

An important capability of Chebfun is automatic Newton iteration for solving nonlinear boundary-value problems (BVPs) of ordinary differential equations (ODEs). In this talk, we describe how path-following techniques for obtaining multiple solutions of nonlinear equations can be extended into function space. Combined with the automatic Newton iteration of Chebfun, it enables Chebfun to find multiple solutions of nonlinear BVPs. Computational examples of the multiple solutions capability will be provided.

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MS121

Chebfun and Equispaced Data

Chebfun is mainly designed to work with data at Chebyshev points. Some linear rational interpolants show good approximation properties with equispaced points and avoid the usual drawbacks of polynomial interpolation with such points. We review a few interpolation schemes as well as their applications and demonstrate how they can be incorporated into Chebfun to make this toolbox also work with equispaced points.

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MS121

Stability of Certain Singular and Singularly Perturbed Differential Equations

We investigate an unexpected phenomenon where problems which are mathematically ill-posed (such as singular ODEs) or ill-conditioned (such as singularly perturbed ODEs) can be reliably solved using spectral methods in coefficient space. This phenomenon is explained by showing that the perturbations present in numerics are in a very restricted class, therefore standard condition numbers do not give a reliable indicator of numerical stability. This approach is applied to reliably solve (to machine precision accuracy) a famous ill-conditioned ODE from Lee and Greengard 1997.

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MS121

Computing on Surfaces with Chebfun2

Chebfun2 can be used to represent several parametric surfaces. In this talk we show how to use the system to compute with functions and vector fields defined on these surfaces. Of particular interest are operators such as gradient, Laplace-Beltrami and divergence.

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MS122

An Optimization Method Based on Piecewise Differentiation

We present an optimization method based on algorithmic or automatic differentiation (AD) for piecewise differentiable objective functions. First, we approximate the target function locally by a piecewise-linear model, having at most a finite number of kinks between open polyhedral facets decomposing the function domain. On each facet we repeatedly solve quadratic subproblems. To switch between the different facets we exploit the structure of the function with the result of disjunctive quadratic subproblems.

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MS122

Generalized Derivatives Via Piecewise Linearization

Abstract not available at time of publication.

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MS122

Evaluating a Clarke Generalized Jacobian of a Piecewise Differentiable Function

Elements of the (Clarke) generalized Jacobian of a locally Lipschitz continuous function are useful in methods for equation-solving and optimization, but can be difficult to compute. This presentation describes a variant of the forward mode of automatic differentiation, in which a generalized Jacobian element is computed for a composition of known elemental nonsmooth functions. This method is computationally tractable, and offers significant computational advantages over existing methods for generalized Jacobian element evaluation.

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MS122

Subdifferential Test for Optimality

We provide a first-order necessary and sufficient condition for optimality of lower semicontinuous functions on Banach spaces using the concept of subdifferential. From the sufficient condition we derive that any subdifferential operator is monotone absorbing, hence maximal monotone when the function is convex.

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MS123

Uncertainty Quantification in Hemodynamics, a Bayesian Approach to Data Assimilation

Computational hemodynamics is experiencing the progressive improvement of measurement tools and numerical methods. We adopt a Bayesian approach to the inclusion of noisy data in the incompressible Navier-Stokes equations. The purpose is the quantification of uncertainty affecting velocity and flow related variables of interest, all treated as random variables. We derive classical point estimators and we obtain confidence regions for the velocity and the wall shear stress, a flow related variable of medical relevance.

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MS123

Nonlinear Stochastic Estimation of Turbulence Subject to Levy Noise

In this work we study the existence and uniqueness of the strong pathwise solution of stochastic Navier-Stokes equation with Ito-Levy noise. Nonlinear filtering problem is formulated for the recursive estimation of conditional expectation of the flow field given back measurements of sensor output data. The corresponding Fujisaki-Kallianpur-Kunita and Zakai equations describing the time evolution of the nonlinear filter are derived. Existence and uniqueness of measure-valued solutions are proven for these filtering equations.

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MS123

Multigrid Methods for Optimal Control Problems in Fluid Flow

Abstract not available at time of publication.

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MS123

Two-Dimensional Stochastic Navier-Stokes Equations with Fractional Brownian Noise

Perturbation of the two-dimensional stochastic Navier-

Stokes equation by a Hilbert-space-valued fractional Brownian noise is studied. With the noise being additive, simple Wiener-type integrals are sufficient for properly defining the problem. Existence and uniqueness of mild solutions are established under suitable conditions on the noise intensities for all Hurst parameter values. Almost surely, the solution's paths are shown to be quartically integrable in time and space. An extension to a multifractal model is given.

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MS124

Gmres Cache Aware Auto-Tuning Strategies for Parallel Architectures

Krylov linear solvers such as GMRES are heavily used with success in various domains and industries despite their complexity. Their convergence and speed greatly depends on the hardware used and on the choice of the Krylov subspace size which is difficult to determine efficiently in advance. We present a study of a cache aware auto-tuning algorithm of the GMRES subspace size on different architectures in parallel which helps the parametrization process while assuring efficient convergence.

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MS124

Petaflop supercomputers, What Programming Model for Seismic Application

Developing efficient Seismic Depth imaging applications on petaflop supercomputer requires to manage hundreds of thousands of parallel tasks. Researchers have to describe and expose the different levels of parallelism: at the interconnect level by describing the explicit data and task distribution, at the compute node level by taking advantage of either homogeneous or heterogeneous technology. In this talk we will discuss how to choose the appropriate programming model in order to preserve scalability and legacy in large-scale implementations

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MS124

Krylov Basis Orthogonalization Algorithms on Many Core Architectures

Efficient and portable iterative linear algebra algorithms on many-core architectures have to be proposed for future supercomputers including large number of accelerators like GPU or MIC. However, using them efficiently requires modifying deeply the conception and the implementation of the algorithms, especially to minimize communications. We present our approach based on the design of generic algorithms using TRILINOS and specialized implementation of BLAS kernels. We apply this approach to Krylov basis generation algorithm on GPU and MIC and we present first results on sparse systems.

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MS124

Programming Model for Sustainable Numerical Libraries for Extreme Scale Computing

Here, we present a modular and multi-level parallelism approach that has a strict separation between computational operations, data management and communication. We illustrate how under this model we are able to design more scalable algorithmic implementations that better exploit their functionalities, scalability and code reusability. The latter is important in the formulation of hybrid numerical schemes. We use the multiple explicitly restarted Arnoldi method as our test case and our implementations require full reuse of serial/parallel kernels in their implementation. Our experiments include comparisons with state-of-the-art numerical libraries on high-end computing systems.

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MS125

Geophysics Meets Spectral Graph Theory: Interferometric Waveform Inversion

Abstract not available at time of publication.

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MS125

Variational Data Assimilation with Sparse Regularization

This paper studies the role of sparse regularization in the variational data assimilation (VDA) problems. Conceptually, this study is focused on data assimilation of noisy and down-sampled observations when the geophysical state of interest exhibits a sparse representation in a properly chosen basis. We show that as long as the sparsity holds, ℓ_1 -norm regularization in the selected basis produces more accurate and stable solutions than the classic data assimilation methods. To motivate further developments of the proposed methodology, examples are provided via assimilating observations into the linear advection-diffusion equation in the wavelet and discrete cosine domains.

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MS125

Sparse Solution of Nonlinear Subsurface Flow Inverse Problems

Abstract not available at time of publication.

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MS125

Seismic Tomography with Sparsity Constraints, at the Global and the Exploration Scale

Seismic tomography leads to gigantic systems of linear equations. As data volumes increase, every effort has to be made to reduce the inversion problem to manageable size. While achieving a reduction of computational complexity, new sparsity-seeking methods should be able to give additional insight into the nature of the problem itself, and the character of the solution. Practically speaking, this means that if we are solving systems that relate data (functionals of seismograms) to model parameters (the physical properties of the Earth) through the use of sensitivity kernels (partial derivatives of the measurements with respect to the unknown Earth parameters), we have opportunities for dimensional reduction on the data, the model, and the kernel side. In this presentation I discusss strategies to make inroads on all three sides of the seismic tomographic inverse problem, using one-, two- and three-dimensional wavelets, and ℓ_2-ℓ_1 combination misfit norms.

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MS126

A Robust Central-Upwind Scheme for 2D Shallow Water Equations

A good numerical scheme for the 2D Saint-Venant system of shallow water equations should satisfy two important features: the scheme should be well-balanced –it exactly preserves "lake at rest' steady states, and the scheme should be positivity preserving –the water depth h remains nonnegative. We present a novel conservative, well-balanced, and positivity preserving central-upwind scheme for Saint-Venant equations. Using several benchmark problems we test the accuracy and robustness of this scheme.

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MS126

A Hamilton-Jacobi Equation for the Continuum Limit of Non-dominated Sorting

Non-dominated sorting is a fundamental problem in multi-objective optimization, and is equivalent to several important combinatorial problems, including a random model for crystal growth. The sorting can be viewed as arranging points in Euclidean space into fronts by repeated removal of the set of minimal elements with respect to the componentwise partial order. We prove that in the (random) large sample size limit, the fronts converge almost surely to the level sets of a continuous function that satisfies a Hamilton-Jacobi equation in the viscosity sense. We then give an efficient numerical scheme for approximating the viscosity solution of this PDE and show how it can be used to approximately solve the non-dominated sorting problem efficiently.

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MS126

Numerical Modeling Methane Hydrate Evolution

Modeling evolution of methane hydrates and in particular of their formation and dissociation is important for energy and climate studies. A numerical model for the corresponding nonlinear degenerate PDE has to account for multiple phases and solubility constraints. With an appropriate formulation using monotone operator techniques and complementarity constraints we obtain convergence results comparable to those for Stefan problem or porous medium equation but with a superior solver performance

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MS126

Numerical Solution of Miscible Displacement under Low Regularity

Miscible displacement flow is one important part of enhanced oil recovery. A polymeric solvent is injected in the reservoir and it mixes with the trapped oil. Accurate simulation of the displacement of the fluid mixture in heterogeneous media is needed to optimize oil production. The miscible displacement is mathematically modeled by a pressure equation (elliptic) and a concentration equation (parabolic) that are coupled in a nonlinear fashion. One challenge in the convergence analysis of numerical methods applied to the miscible displacement arises from the fact that the diffusion-dispersion coefficient in the concentration equation is unbounded. In this work, we formulate and analyze discontinuous in time methods coupled with several finite element methods (including mixed finite elements and discontinuous Galerkin) for the miscible displacement. The diffusion-dispersion coefficient is not assumed to be bounded. Other coefficients in the problem are not assumed to be smooth. Convergence of the numerical solution is obtained using a generalization of the Aubin-Lions compactness theorem. The Aubin-Lions theorem is not applicable since the numerical approximations are discontinuous in time. Numerical examples with varying order in space and time are also given.

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MS127

The Challenges of Wind Prediction from a Forecast Sensitivity Perspective

Successful wind prediction with a numerical model relies, in part, on accurate initial conditions. The chaotic nature of the atmospheric attractor results in large spatial variability in the sensitivity of wind forecasts to the initial state, resulting in different initialization techniques providing large forecast differences. Ensemble mean forecasts can also diverge from the model attractor in the presence of significant nonlinear perturbation growth. These challenges for wind prediction will be discussed in this presentation.

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MS127

Statistical Applications of Offsite Meteorological Measurements for Short-Horizon Wind Power Prediction

Many meteorologically-driven wind generation "ramps" re-

sult from passage of mid-latitude weather systems across wind farms. Measurements upstream of these features can be provided to statistical and time series models for forecasting in the sub-hourly to 6 hour horizons. We demonstrate the application of advanced time-lagged and other time series modeling for improved wind power forecasting, wherein such models make best use of offsite telemetry to improve prediction, relative to standard numerical weather models and persistence.

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MS127
Stochastic Learning Methods for Solar Forecasting

We discuss a number of different techniques for extracting relevant information from cloud temporal patterns and their effect on the quality of solar irradiance forecasts at the ground level. The methods used here are validated against high-quality, ground-truth solar data for several locations in the Pacific Rim. The performance of the methods is determined in comparison to a diurnally corrected, history length optimized persistence model.

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MS128
A Mathematical Framework for Critical Transitions: Normal Forms, Variance and Applications

Abstract not available at time of publication.

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MS128
Asymptotics of Stochastically and Periodically Forced Tipping: Advance Or Delay

We compare the effects of different types of variability on transitions near a tipping point. Through an asymptotic analysis based on multiple scales and WKB-type approximations, we consider the relative effects of noise, periodic variability, and slowly varying control parameter. The approach is applied in canonical models and in a global energy balance model for average ocean temperature where asymmetry also plays a role. Results are reported in the context of indicators for tipping point proximity and energy balance models for sea ice.

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MS128
Tipping Points: Overview and Challenges

Abstract not available at time of publication.

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MS129
Self-Convexity

(Joint work with Carlos Beltrán, Jean-Pierre Dedieu and Mike Shub). Let $(\mathcal{M}, \langle \cdot, \cdot \rangle_{\S})$ be a **smooth** Riemannian manifold and $\alpha : \mathcal{M} \to \mathcal{R}_{>\prime}$ be a **Lipschitz** function. We can endow the manifold M with a new metric, namely

$$\langle \cdot, \cdot \rangle'_x = \alpha(x) \langle \cdot, \cdot \rangle_x$$

which is conformally equivalent to the previous one. This new norm will be called the **α-metric** and sometimes the **condition metric**. It defines a **Riemann–Lipschitz** structure on $\mathcal{M}$.

Definition: We say that α is **self-convex** if and only if, for any **geodesic** γ in the α-structure, $t \mapsto \log \alpha(\gamma(t))$ is a convex function.

Self-convexity came out from the complexity analysis of certain homotopy algorithms for solving polynomial systems.

I will try to survey the main results and open questions. For instance:

Theorem: *The square of the condition number for linear equation solving is self-convex.*

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MS129
Hamiltonian Approach to Geodesics Computation in Condition Metric

Abstract not available at time of publication.

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MS129
Title Not Available at Time of Publication

Abstract not available at time of publication.

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MS130

Inverse Problems with Internal Information

Abstract not available at time of publication.

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MS130

Inverse Source Problem for the Wave Equation with an Uncertain Wave Speed

We consider the inverse source problem for the wave equation that arises as a part of the photoacoustic tomography problem. This problem can be solved in a stable way if the wave speed is known and non-trapping. However, in practice the wave speed is know only up to some uncertainty and we consider how a modelling error in the wave speed affects on the reconstruction of the source.

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MS130

Inverse Problems in Quantitative Fluorescence Photoacoustic Tomography

Quantitative fluorescence photoacoustic tomography (QfPAT) combines quantitative photoacoustic tomography with fluorescence tomography to achieve high-resolution imaging of spatial concentration of fluorescent biochemical markers in target tissues. Mathematically, quantitative fluorescence photoacoustic tomography can be regarded as an inverse coefficient problem for a weakly coupled system of diffusion equations with interior absorbed energy data. We present in this talk some uniqueness and stability results as well as reconstruction strategies for such an inverse problem.

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MS130

Quantitative Photoacoustic Tomography

I will present two recent works for quantitative photoacoustic imaging. We present a Neuman series based iterative algorithm that can recover the initial wave field efficiently and accurately in the first step. The second step is to reconstruct optical properties of the medium using internal measurements from the reconstructed acoustic source distribution from the first step. We propose a hybrid reconstruction procedure that uses both interior measurement and boundary current data, which is usually available in diffuse optical tomography.

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MS131

Stochastic Models of Cancer Evolution

We study the accumulation of mutations in a spatial Moran model on a torus in which each cell gives birth at a rate equal to its fitness and replaces a neighbor at random with its offspring.

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MS131

Numerical Techniques for Optimal Sequential Experimental Design via Dynamic Programming

How do we select the sequence of experiments that maximizes the value of costly experimental data? We formulate this optimal sequential experimental design problem using dynamic programming, taking into account the expected uncertain future effects. We solve it numerically using approximate dynamic programming (ADP) methods. Two major numerical issues are addressed: the representation of posterior distributions in a sequential Bayesian inference context, and the choice of features in value function approximation ADP technique. Preliminary results are demonstrated on a proof-of-concept model problem.

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MS131

A Multi-stage Sparse Grid Collocation Method for Stochastic Differential Equations with White Noise

We propose a new method for long-time integration of linear stochastic partial differential equations by combining sparse grid collocation (SGC) with a multi-stage recursive procedure. We show theoretically and numerically that SGC yields satisfactory accuracy only for small magnitude of noise and small integration time. Combining SGC with a multi-stage approach we present a numerical example to show the effectiveness in long-time integration of the combined method for a stochastic advection-diffusion equation.

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MS132

BV Estimate for Isentropic Gas Dynamics

Abstract not available at time of publication.

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MS132

Asymptotic Preserving Schemes for Low Mach Number Flow

We present new asymptotic preserving large time step methods for low Mach number flows. They belong to the class of genuinely multidimensional schemes and are developed for both finite volume and discontinuous Galerkin framework. Nonlinear fluxes along cell interfaces are evaluated by means of the genuinely multidimensional evolution Galerkin operators. The key property of the method is that they are asymptotic preserving with respect to small Mach number. In order to take into account multiscale phenomena nonlinear fluxes are splitted into a linear part governing the acoustic and gravitational waves and to the rest nonlinear part that models advection. Time integration is realized by the IMEX type approximation. We present results for some standard meteorological test cases with small Mach numbers or for the shallow water flows with small Froude numbers. This research is done in collaboration with S. Noelle (Aachen), K.R. Arun (Trivandrum), L. Yelash (Mainz), G. Bispen (Mainz), F.X. Giraldo (Monterey) and A. Mueller (Monterey). Thanks to the German Science Foundation DFG LU 1470/2-2.

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MS132

Existence Results for a Model of the Compressible Mixtures Flow

We consider the Cauchy problem for the system of equations governing flow of reactive mixture of compressible gases [V. Giovangigli: *Multicomponent flow modeling.* Birkhäuser Boston Inc., 1999]. We will present the proof of sequential stability of weak solutions when the state equation essentially depends on the species concentration and the viscosity coefficients satisfy the relation proposed in [D. Bresch and B. Desjardins: *On the existence of global weak solutions to the Navier–Stokes equations for viscous compressible and heat conducting fluids.* J. Math. Pures Appl., 2007], in particular, they vanish on vacuum. We shall also discuss the main steps of the approximation procedure, under additional assumption on the cold component of the pressure in the regions of small density [E. Zatorska: *On the flow of chemically reacting gaseous mixture.* JDE, 2012].

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MS133

Results and Applications from a Generalized Software Framework for Treecode/FMM

Research in building treecode/FMM software has largely been focused in three areas: mathematical analysis and control of kernel expansions, parallel tree representation and construction, and parallel tree traversals. In this talk, we present a generalized software framework in which these research areas are mostly independent. That is, we have incorporated new kernels and expansions without modifying the tree construction or traversal and included recent parallel computing strategies without modification of the kernels. We will show benchmarks, profiles, and applications to a simple N-body example as well as a preconditioned BEM for molecular modeling.

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MS133

Parallel Higher-order Boundary Integral Electrostatics Computation on Molecular Surfaces with Curved Triangulation

We present a parallel higher-order boundary integral method to solve the linear Poisson-Boltzmann (PB) equation. The molecular surfaces are first discretized with flat triangles and then converted to curved triangles with the assistance of normal information at vertices. To maintain the desired accuracy, four-point Gauss-Radau quadratures are used on regular triangles and sixteen-point Gauss-Legendre quadratures together with regularization transformations are applied on singular triangles. In addition, the schemes are parallelized with MPI implementation.

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MS133

A Petascale Fast Multipole Method for Volume Potentials

We present a highly scalable solver for volume potentials using piecewise polynomials and adaptive octree to represent the source distribution and the output potential. Our method uses the kernel independent FMM to allow for the use of a wide range of kernels, such as: Laplace, Stokes, Helmholtz etc. We present convergence results for these kernels with freespace and periodic boundary conditions.

We discuss algorithmic details for distributed memory parallelism using MPI and shared memory parallelism on multicore CPUs and manycore accelerators on the Stampede and Titan supercomputers. BLAS, FFTW and SSE optimizations are used to achieve high FLOP rates.

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MS133

An Approximate Deflation Preconditioning Method Based on Multiple Grids for Wave Scattering Problems

In this talk I consider the Lippmann-Schwinger (LS) integral equation for inhomogeneous acoustic scattering. I demonstrate that spectral properties of the LS equations suggest that deflation based preconditioning might be effective in accelerating the convergence of a restarted GMRES method. I will present an analytical framework for convergence theory of general approximate deflation that is widely applicable. Furthermore, numerical illustrations of the spectral properties also reveal that a significant portion of the spectrum is approximated well on coarse grids. To exploit this, I develop a novel restarted GMRES method with adaptive preconditioning based on spectral approximations on multiple grids.

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MS134

On Order Derivatives of Bessel Functions

New representations are derived for the derivatives with respect to order for Bessel functions of the first and second kinds. These involve integrals of the products pairs of Bessel functions and the reciprocal function. New expansions are derived for two of these integrals, complementary to a known expansion for the third. The uniform asymptotic behavior of the derivative with respect to order for the J and Y Bessel functions is also investigated.

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MS134

The Generalized Christoffel Functions and Extremal Problems

The bounds and asymptotics of the classical L2-Christoffel functions are very important in the theory of orthogonal polynomials and in their applications. The more general Lp-Christoffel functions are less understood. While the bounds for these are well known, asymptotics have never be established for . We show how such asymptotics can be described in terms of an extremal problem in a special space of entire functions. As a consequence, we deduce an asymptotically sharp Nikolskii inequality.

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MS134

Universality Limits for Random Matrices and Orthogonal Polynomials

Universality limits for random matrices describe phenomena such as spacing and distribution of eigenvalues. Orthogonal polynomials play a key role in the analysis, when the class of matrices are Hermitian. We survey some recent progress in this topic.

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MS134

Spectral Transforms and Orthogonal Polynomials

Let G be an analytic region and let m be a measure on that region. It is known that for certain regions G and measures m, the corresponding orthogonal polynomials admit Szego asymptotics on the exterior of the closure of G. Under stronger hypotheses, one can deduce that the orthogonal polynomials admit Szego asymptotics on an even larger region that includes the entire boundary of G. In this talk, we will discuss some ways to modify measures that do not destroy this phenomenon of the orthogonal polynomials admitting Szego asymptotic inside the region G. This is joint work with Erwin Mina-Diaz.

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MS135

Mathematical Problems in the Diagnosis and Treatment of Disease

It will be explained how the following problems in the diagnosis and treatment of breast cancer have led to mathematical problems: 1. How can one improve the diagnosis of breast cancer? 2. How can one determine the growth rate of a cancer once it has been detected? 3. In which order should drugs be given in order to improve relapse and survival times? The first problem led to the design , construction, and testing of an electrical impedance spectroscopy system combined with an x- ray mammography system. The second problem led to a quantitative model to predict the growth rate of some cancers as a function of the number of Her2 and EGF receptors on the cells involved. The third problem led to quantitative models capable of predicting the outcome of specific chemotherapy regimens used by Bonadonna involving the use of CMF and A (Doxorubicin) for the adjuvant treatment of breast cancer.

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MS135

Comparison of Bipolar Injection Patterns in Terms of Noise Propagation, Image Quality and Observability

Bipolar current sources in electrical impedance tomography simplifies the hardware and it is a common hardware architecture nowadays. However, it is not clear which is the best current pattern and measurement pattern for lung monitoring. The present numerical simulations compares skip-n bipolar patterns in terms of noise propagation and image quality.

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MS135

Benefits of using Anatomical and Physiological Priors in Electrical Impedance Tomography: Experimental Results

Anatomical and physiological information from pigs thoraces were used to build statistical priors for electrical impedance tomography. The benefits of using this prior and the approximation error method in Gauss-Newton and Kalman Filter algorithms is demonstrated using in vivo data from pigs and human volunteers.

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MS135

Reconstructions of Lung Pathologies by a D-Bar Method for 2-D Electrical Impedance Tomography

A D-bar method for computing 2-D reconstructions of conductivity and permittivity from EIT data is described. Reconstructions from numerically simulated data and in vivo human subject data are presented illustrating the method's potential for clinical lung applications.

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MS136

Optimal Methods for a Class of Composite Variational Problems

Abstract not available at time of publication.

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MS136

Polynomial Optimization with Real Varieties

We study the optimization problem

$$\min \quad f(x) \quad s.t. \quad h(x) = 0,\ g(x) \geq 0$$

with f a polynomial and h, g two tuples of polynomials in $x \in R^n$. Lasserre's hierarchy is a sequence of sum of squares relaxations for finding the global minimum f_{min}. Let K be the feasible set. We prove the following results: i) If the real variety $V_R(h)$ is finite, then Lasserre's hierarchy has finite convergence, no matter the complex variety $V_C(h)$ is finite or not. This solves an open question in Laurent's survey. ii) If K and $V_R(h)$ have the same vanishing ideal, then the finite convergence of Lasserre's hierarchy is independent of the choice of defining polynomials for the real variety $V_R(h)$. iii) When K is finite, a refined version of Lasserre's hierarchy (using the preordering of g) has finite convergence.

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MS136

Inexact BOSVS Algorithm for Ill-Posed Inversion with Application to PPI

This paper proposes an Inexact Bregman operator splitting algorithm with variable stepsize (Inexact BOSVS) for solving problems of the form $\min_u \phi(Bu) + 1/2\|Au - f\|_2^2$, where ϕ may be nonsmooth. The original BOSVS algorithm uses a line search to achieve efficiency, while a proximal parameter is adjusted to ensure global convergence whenever a monotonicity condition is violated. The new Inexact BOSVS uses a simpler line search than that used by BOSVS, and the monotonicity test can be skipped. Numerical experiments based on partially parallel image reconstruction compare the performance of BOSVS, inexact BOSVS, and BosNewton, a Newton-Based Bregman Operator Splitting scheme.

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MS136

The Limited Memory Conjugate Gradient Method

In theory, the successive gradients generated by the conjugate gradient method applied to a quadratic should be orthogonal. However, for some ill-conditioned problems, orthogonality is quickly lost due to rounding errors, and convergence is much slower than expected. A limited memory version of the conjugate gradient method will be presented. The memory is used to both detect the loss of orthogonality and to restore orthogonality. Numerical comparisons to the limited memory BFGS method (L-BFGS) will be also discussed.

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MS137

High-Order Positivity Preserving Methods for Hyperbolic Equations

The construction and use of high-order positivity preserving methods for hyperbolic equations is described. The methods derived are constructed using data-bounded polynomials with bounded derivatives, used within the framework of ENO or WENO methods. Examples of results obtained with these approaches will be given together with a comparison against other high-order positivity preserving approaches.

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MS137

Threshold Dynamics for Networks with Arbitrary Surface Tensions

Abstract not available at time of publication.

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MS137

Further Study of the Back and Forth Error Compensation and Correction Method for Advection Equations and Hamilton Jacobi Equations

We further study the properties of the back and forth error compensation and correction (BFECC) method for advection equations such as those related to the level set method and for solving Hamilton-Jacobi equations on unstructured meshes. In particular, we develop a new limiting strategy. This new technique is very simple to implement even for unstructured meshes and is able to eliminate artifacts induced by jump discontinuities in derivatives of the solution as well as by jump discontinuities in the solution itself (even if the solution has large gradients in the vicinities of a jump). Typically, a formal second order method method for solving a time dependent Hamilton-Jacobi equation requires quadratic interpolation in space. A BFECC method on the other hand only requires linear interpolation in each step, thus is local and easy to implement even for unstructured meshes. Collaborators: Lili Hu and Yao Li.

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MS137

Parametrized Maximum Principle Flux Limiters for High Order Schemes Solving Hyperbolic Conservation Law

Maximum principle preserving is an important property of the entropy solution, the physically relevant solution, to the scalar hyperbolic conservation laws. One would like to imitate the property on the numerical level. On the other hand, preserving the maximum principle also provides a stability to the numerical schemes for solving the conservation law problem. The challenge exists when solving the conservation law problems with high order schemes in a consistent and conservative framework. In this talk, we will discuss how this problem is addressed by introducing a series of maximum principle constraint. By decoupling those constraints, a parametrized flux limiting technique is developed to make sure the numerical solution preserves maximum principle in the conservative and consistent manner while the scheme is still high order. Generalization of the technique to convection-diffusion problem will also be discussed. Potential application of this method will be explored in the future work.

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MS138

Unimodulariy and Conservation of Volumes in Nonholonomic Mechanics

In this talk I will show how the geometric structure that underlies the equations of motion of a nonholonomic mechanical system with symmetry can be exploited to obtain necessary and sufficient conditions for the existence of an invariant volume. Using our method we have shown existence and non-existence of an invariant measure for several concrete mechanical problems that will be discussed in detail.

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MS138

The Geometry of Phase Space Lifts: From Maxwells Equations to Radiative Transfer Theory

We study the geometry of the phase space lift of Maxwell's equations that in the short wavelength limit leads to radiative transfer theory. We introduce a geometric density operator for the electromagnetic field, which, as we show, is equivalent to known optical coherence "matrices". With this operator, Maxwell's equations can be written in commutator form which allows us to lift electromagnetic theory to the cotangent bundle where time evolution is governed by a matrix-valued Moyal-bracket.

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MS138

Symplectic Semiclassical Wave Packet Dynamics

I will talk about the geometry and dynamics of semiclassical wave packets, which provide a description of the transition regime from quantum to classical mechanics by placing "quantum mechanical wave flesh on classical bones." I will formulate semiclassical mechanics from the symplectic-geometric point of view by exploiting the geometry of quantum mechanics. This approach effectively "strips away" quantum effects from quantum mechanics and incorporates them into the classical description of mechanics.

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MS138

An Euler-Poincare Description of Curve Matching

In image analysis, the following question often arises: given two curves in the plane (or two images, or other geometric objects), how (dis)similar are these curves? We address this question using curves of deformations in a (finite-dimensional) Lie group. In this talk, I will focus on the group of Euclidean isometries, showing that the equations for morphing arise as constrained Euler-Poincare equations. At the end, some illustrative examples will be presented.

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MS139

H Infinity Feedback Boundary Stabilization for Incompressible Fluid Flow

We study the robust or H^∞ exponential stabilization of the linearized Navier Stokes equations around an unstable stationary solution in a two-dimensional domain Ω. The disturbance is an unknown perturbation in the boundary condition of the fluid flow. We determine a feedback boundary control law, robust with respect to boundary perturbations, by solving a max-min linear quadratic control problem. We show that this feedback law locally stabilizes the Navier Stokes system. Similar problems have been studied in the literature in the case of distributed controls and disturbances. The case of boundary controls and boundary disturbances has been addressed in the current work.

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MS139

Investigation of Steady NS Flows past a Cylinder using a Spectral Method, which basis Functions Spans the Infinite Domain

The main difficulty in calculating steady flow past a cylinder in 2D is due to the slow rate in which the velocity approaches its asymptotic value. We have developed a spectral technique for finding solutions in the exterior domain. The talk will also introduce the "bootstrap" method. In the "bootstrap" method, the solution to steady NS is calculated as a perturbation to solution of the Oseen system.

The results are compared with Fornberg (1985).

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MS139

Dynamics of Inertial Particles in Viscous Flows Driven By Oscillating Cilia

Aquatic microorganisms like Vorticella use oscillating cilia to establish streaming flows that capture nearby food particles. Artificial cilia can be used to achieve similar particle capture and transport in engineered systems. This talk will describe the analytical, computational, and experimental investigation of inertial particle dynamics in planar viscous flows driven by systems of circular cylinders executing rectilinear vibrations.

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MS139

Optimal Reconstruction of Constitutive Relations in Complex Multiphysics Phenomena

We consider optimal estimation of state-dependent constitutive relations in complex multiphysics systems governed by PDEs. We will demonstrate that such problems can be formulated in terms of PDE-constrained optimization where solutions can be obtained using suitable gradient-based techniques. Since the control variable is defined as a function of the state, the cost functional gradients have a rather unusual structure and their computation leads to a number of interesting questions at the level of numerical analysis.

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MS139

Mathematical Approaches to Stochastic Signaling and Pattern Formation

In biological systems with many genes and proteins presenting in small numbers, the inherent fluctuations can be large and a continuous description of changes of concentrations is often not sufficient. In this talk, we will present our analysis and computations of discrete stochastic models governed by master equations for the changes of numbers of molecules, to understand what strategies are used to control noise propagation and refine gene expression regions. Our results imply a lot of interesting consistency between discrete stochastic systems and the corresponding continuous ones.

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PP1

Adomian Polynomial Approximation to Reaction diffusion Equation Using Fractional Derivatives

The fractional derivative concepts are used to understand the pattern formation of cells in biological system by reaction diffusion equation. The goal of this research is to improve the solution and models a more realistic representation using the sensitivity of fractional differential equations, which is approximated by Adomian polynomials. The solution methodology and the diffusion processes are demonstrated with computer simulation and the algorithms are developed using the environment of MATLAB and COMSOL. The results are compared with the existing literature. Also, the sensitivity of parameters which controls the pattern formation and various other techniques will also be discussed.

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PP1

Roots of Quadratic Interval Polynomials

In this paper, we study the zeros of interval polynomials. We develop a method to compute all zeros of such polynomial with interval coefficients and give the characterization

of the roots.

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PP1

AWM Workshop A Mathematical Model of Denitrification in Pseudomonas Aeruginosa

Lake Erie has witnessed recurrent low-oxygen dead zones and related microbial production of greenhouse gas, nitrous oxide, which is an intermediate in complete denitrification, a microbial process of reduction of nitrate to nitrogen gas. We present a discrete model of denitrification metabolic network in Pseudomonas aeruginosa, one of the taxa performing denitrification in Lake Erie. This work suggests that phosphate highly affects the dynamics of the network by inhibiting the major regulator of the system.

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PP1

Parameter Estimation with Censored Data Via Kalman Filtering

It has been shown that the Kalman Filter does not perform well when output measurements are censored. This work considers a modified Kalman filter that properly utilizes the information provided by censored measurements. We apply this methodology to parameter estimation in a nonlinear ODE model for hepatitis C viral dynamics and compare the results to those obtained with maximum likelihood estimation.

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PP1

Improved Power Forecasting Using Pid Control Theory and Principal Component Analysis

This research is a novel method to accurately define the behavior of individuals controlling climate surrounding and represented by a discrete proportional integral derivative (PID) controller. This research uses principal component analysis and PID to make a power consumption forecasting model based on historical and predicted temperature data.

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PP1

Optimal Bayesian Inference in Social Networks

Understanding how information propagates in a social network has been an active area of research over the last few decades. It is frequently assumed that discussion improves the decisions of individuals. However, such exchanges can negatively impact a collective decision. Then how should observers integrate information to reach best decisions? We establish a general result on how the individuals can achieve optimal inference in presence of redundancies in a graphical Bayesian model of interacting observers.

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PP1

Long-Time Asymptotics for Perturbations of the Toda Lattice

We consider one dimensional doubly-infinite Fermi-Pasta-Ulam (FPU) lattices obtained via perturbations of the completely integrable Toda interaction potential. We investigate, via numerical methods, the long time asymptotics of these nearly integrable systems. In particular, we aim to relate the asymptotic resolution into solitary waves in the perturbed systems to the soliton resolution in the integrable lattice, namely the Toda lattice.

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PP1

AWM Workshop Derivation of SPDEs for Correlated Random Walk Models

Organisms do not move in purely random directions. Often, the current direction is correlated with the prior movement. This type of random walk is called a correlated random walk. In this study, correlated random walk models are studied, specifically, the telegraph equation in one-dimension and the linear transport equation in two dimensions. Dynamical system is constructed to determine the different independent changes. Finally stochastic telegraph and linear transport equations are derived from basic principles.

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PP1

Domain Decomposition with Interface Phenomena and Application to Modeling Solar Cells

We consider domain decomposition techniques for the drift-diffusion system in a semiconductor with a material interface. The difficulties are in accounting for nonhomogeneous jumps in the primary variables which are caused by the potential offset at the heterojunction, as well as accounting for the thermionic emission model at the heterojunction in the transport equations. We show that adapted forms of the Neumann-Neumann algorithm work very well for this problem.

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PP1

Successive Constraint Methods in the Collocation Reduced Basis Framework

Successive Constraint Methods are used to efficiently evaluate an accurate lower bound for the 'inf-sup' constant needed to numerically solve parametric Partial Differential Equations using the Reduced Basis Method(RBM). The RBM, originally developed in the Galerkin framework, has recently been extended for the collocation methods. We present adapted and new formulations and numerical implementations of the Successive Constrain Method to cope with the unique challenges inherent to the Collocation Framework.

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PP1

An Exploration of Dynamical Systems with An Application in Cancer Growth

As we encounter natural systems, there is a need to design simple but accurate mathematical modeling and simulations in order to prevent serious errors. Nowhere is such work needed more than in medicine and in particular with cancer research. We propose a model using differential equations and dynamical systems to study cell development and tumor growth (or any similar dynamical progression). The model is solved numerically and compared with experimental data to provide additional insight.

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PP1

Finding Singular Solutions to Polynomial Systems with Perturbed Regeneration

Homotopy continuation theory is used to find solutions to systems of polynomial equations. Additionally, numerical algebraic geometry, a relatively young and quickly growing field, utilizes continuation methods to find and classify positive-dimensional solutions. An overview of the field will be given for beginners. For active researchers in the field, perturbed regeneration will be given to efficiently approximate singular isolated solutions for which standard regeneration only does with possibly many costly deflations to regularize them."

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PP1

Heterogeneous Multiscale Method for Steady State Poroelasticity

In this work, we apply the heterogeneous multiscale method coupling discrete and continuum scale models governing flow and deformation processes in porous media. We derive a multidimensional model for the steady state case and propose a numerical scheme to solve the dynamic multiscale pde as a sequence of steady state multiscale poroelasticity equations.

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PP1

AWM Workshop Applications and Recent Developments of Multilevel Optimization Framework (MG/OPT)

This talk will present recent progress related to the theory and applications of the multilevel optimization approach MG/OPT. The intent of MG/OPT is to use calculations on coarser levels to accelerate the progress of the optimization on the finest level. Significant speedup by using MG/OPT comparing to other existing techniques has shown for a particular type of tessellation problems called centroidal Voronoi tessellations(CVTs) and a variety of other constrained optimization problems.

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PP1

Detecting Changes in Weather Data Streams for Wind Energy Prediction

Wind generation is highly correlated to weather conditions. We are investigating if we can predict ramp events, which are large changes in generation over short periods, by monitoring the weather data near the wind farms. Using velocity density estimation, we determine the trends in the evolution of these data streams considering both temporal and spatial properties. We discuss how the density profiles can detect changes in weather and relate them to wind generation.

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PP1

AWM Workshop Parallel in Time Using Multigrid

One of the main challenges facing computational science with future architectures is that faster compute speeds will be achieved through increased concurrency, since clock speeds are no longer increasing. As a consequence, traditional time marching will eventually become a huge sequential bottleneck, and parallel in time integration methods are necessary. This poster discusses optimality and parallelization properties of one approach for parallelization in time, namely a multigrid-in-time method that is fairly unintrusive on existing codes.

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PP1

Study of Weakly Discontinuous Solutions for Hyperbolic Differential Equations Based on Wavelet Transform Methods

A new way to prove the one-dimensional Cauchy problems weakly discontinuous solutions for hyperbolic PDEs are on the characteristics is discussed in this paper. To do so, I use wavelet singularity detection methods based on two-dimensional wavelet and combine it with the Lipschits index to strengthen the detection.

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PP1

AWM Workshop Gene Expression: Diffusion Equations Model and Numerical Simulations

A mathematical model was created using coupled PDEs to illustrate the interactions between one miRNA segment and several mRNA segments within tissue. The coupled PDE system can be studied as three separate well-posed systems of equations: a unique, nonlinear diffusion equation, coupled diffusion equations at steady state, and coupled diffusion equations with time dependence. Stable numerical simulations show sharpening in concentration profiles of mRNA in tissue when miRNA has mobility.

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PP1

Can Cfa Franc Promote the Trade Between the Waemu (West African Economic and Monetary Union) and Its Trading Partners?

This paper discuss briefly the implications of the peg exchange rate CFA-Euro on the trade in the West African Economic and Monetary Union (WAEMU) based on the framework of SHANE-ROE-SOMWAPU, optimal control and the real business cycle theories. Hence, the study aims to show by econometrical estimation under the international market clearance condition, the effect of the exchange rate on the trade in WAEMU. It analyzes deeply the dynamic propagation mechanism of the rate of change of the exchange rate on the exportation volume, consumption, and foreign interest rate. Definitely, the exchange rate seems to be an important macroeconomic variable affecting the trade between WAEMU and its trading partners such the European Union, USA, China, etc. We find that the depreciation of the exchange rate will be effective if the real value of the exportation and the consumption is greater than one percent increase of the foreign interest rate.

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PP1

Wavelets and Wavelet Packets on Point Clouds

This research generalizes wavelet packets to data on networks, with the aim of using these wavelet packets for compression and as a feature extractor for classification. We develop two wavelet packet transforms, the foundations of which are (1) the average-interpolation wavelets of Rustamov and (2) the lifting scheme of Jansen, Nason, and Silverman. A basis must then be selected from among these wavelet packets. For compression, this is done via the best-basis algorithm of Coifman and Wickerhauser. For classification, we use the local discriminant basis algorithm of Saito and Coifman. Future work will use investigate the effectiveness of these wavelet packets for compression and classification.

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PP1

AWM Workshop Finite-Sized Reproductive Numbers

A diseases basic reproductive number, R0, is the average number of infections caused by an infectious individual in a susceptible population. This key epidemiological quantity is used to inform models of diseases spread and persistence. The classic formulation of R0 assumes an infinite population, and is problematic when effective population size is small. We discuss the theory of finite-population reproductive numbers, and calculate some for simple models of directly transmitted and vector-borne diseases.

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PP1

Optimization of Pool and Tournament Play in the Top Swedish Handball League

We present research arising from the schedule-design problem for the top Swedish Handball League, Elitserien, whose schedule includes both geographic group play and a double round-robin tournament. While both round-robin and pool play have been addressed by researchers, little attention has been paid to issues arising from their combination. We construct desirable home-away pattern sets to yield greatly improved schedules for leagues such as Elitserien (which will use our results in their 2013-2014 season).

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PP1

AWM Workshop Optimizing Intermittent Water Supply

Water distribution systems throughout the world operate under intermittent supply. Efficient solvers for transient flow problems in water pipes are a prerequisite for optimization methods to develop effective management techniques for such systems. This work investigates inexact Riemann solvers to inform a model for coupled pipes in a water distribution network, in order to implement optimization over operational scenarios to achieve more equitable distribution of water and reduce wear on system components.

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PP1

Comparative Analysis of Multiphase Flow Simulation in Fractured Rock Using Asynchronous and Synchronous Time Stepping Schemes on Hybrid Finite Element-Finite Volume Meshes

In adaptively refined discrete fracture and matrix (DFM) models, flow velocity varies over many orders of magnitude and the smallest cells of the unstructured grid often feature the highest flow velocities. Thus, global CFL is prohibitively small, but overstepping it in implicit calculations is a challenge because of the nonlinear saturation functions and the risk of ill-conditioned matrices due to large scale difference in velocities and mesh resolution. We illustrate this with field-data based DFM models, comparing performance and accuracy of implicit methods with our original discrete event simulation (DES) based one that facilitates asynchronous time stepping.

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PP1

Estimating the Violation of the Kkt Conditions

Given x, not necessarily a local minimizer of an optimization problem, we propose a quantitative way of estimating how close x is to a solution of the KKT conditions. This estimate of the distance to a KKT point is the solution of a non-convex optimization problem. We show how to solve this problem using an Active Set Algorithm (ASA) .

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PP1
Robust Parameter Estimation: a Bayesian Inference Approach

When policy makers are called to act on the control of epidemic they often face the problem of how to efficiently allocate limited resources in order to minimize disease impact. To help aid policy makers in their decision-making, we focus on improving the current methodology for estimating transmission parameters by fusing a Bayesian statistical framework with a stochastic model of disease transmission and making this formulation applicable to any disease. This method allows us to account for measurement error in disease census data thus providing more robust parameter estimates. Increasing estimation accuracy through the adoption of our framework will equip policy makers with better tools for mitigating the effects of an epidemic.

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PP1
Predicting Fetal Distress

During labor, continuous fetal heart rate (FHR) monitoring is not a reliable predictor for severe academia. This condition is commonly caused by umbilical cord occlusions and can cause fetal distress and permanent brain injuries to the fetus. More reliable monitoring modalities and methods of signal analysis are needed. To address this, I present a mathematical model which explores the monitoring of two signals, FHR and electroencephalogram (EEG), as a way to predict fetal distress.

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PP1
Fundamental Niche Character in a Temporally Varying Environment

The magnitude and extent of variation that an organism's niche inherits from its environment is investigated through a temporally varying chemostat model. Constrained optimization is used to predict how an organism should optimally respond to environmental variation occurring over several different time scales. Light data collected near Mushroom Spring, Yellowstone National Park, are then incorporated into the model and the output is compared to the observed light niche of a phototrophic Mushroom Spring inhabitant.

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PP1
Micellar Formulations of Drug Modified Copolymers with Single Walled Carbon Nanotube for Drug Delivery

Computer simulations are being carried out to understand the maximum therapeutic efficacy of drugs by controlling the bio-distribution profile. Micelle formation by the addition of surfactant / polymeric hydrophobic- hydrophilic-copolymers (PHBC) in mixtures with the hydrophobic drugs have been studied as drug delivery systems. PBHC can form either lamellar or rod-like , cylindrical, spherical, and hexagonal aggregates morphology, with different solubilization capacity under certain conditions. These have different sizes and stability criteria and be used to solubilize water insoluble drugs for the treatment of infectious disease. In order to understand these limitations we have made an attempt to study the effect of functionalized drugs by dissipative particle dynamics (DPD). Further, we simulated the system in the presence of single walled carbon nanotube (SWNT) as a site- specific drug carrier.

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PP1
Variance Reduction for Multilevel Monte Carlo Simulation of SDEs

A prototypical problem in stochastic differential equations (SDEs) is to compute the expectation of some functional - called the payoff - of the SDE's solution. The multilevel Monte Carlo (MLMC) method, introduced in [M.B. Giles, Operations Research, 56(3):607617, 2008], dramatically improves upon naive Monte Carlo methods for such problems. We present two improvements to MLMC methods, applicable when the payoff is twice differentiable. The first eliminates the variance at the lowest level by making use of Ito's lemma, while the second improves the scaling of the variance of the level differences in order to achieve the theoretically optimal computational complexity. Numerical examples are presented that confirm the results.

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PP1
AWM Workshop Feedback-Mediated Dynamics in

the Kidney: Mathematical Modeling and Analysis

We developed a mathematical model of the tubuloglomerular feedback (TGF) system in the kidney to study TGF-mediated oscillations in fluid dynamics variables. Model equations consist of nonlinear time-delayed differential equations. Using bifurcation analysis and numerical simulations, we investigated the impacts of parameter variabilities on model behaviors. Model results revealed a complex parameter region, where qualitatively different solutions are possible. The multistability of model solutions may explain the emergence of irregular oscillations in spontaneously hypertensive rats.

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PP1

AWM Workshop Light Propagation In Semiconductor-Based Luminescent Solar Concentrators

Luminescent solar concentrators (LSCs) convert sunlight to electricity. We study light propagation in LSCs that contain semiconductor nanoparticles and use this to predict their performance and optimal design parameters. In particular, a luminescent radiative transport theory is proposed that can take the reabsorption effects into account accurately. The computational results based on the deterministic theory are studied in detail and compared with Monte Carlo simulations for photon transport. The results of this study will aid the development of highly-efficient LSCs.

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PP1

AWM Workshop—Global Existence for Surface/Interior Reaction Diffusion Systems

We consider coupled reaction-diffusion models, where some components react and diffuse on the boundary of a region, while other components diffuse in the interior and react with those on the boundary through mass transport. Classical potential theory and estimates for linear initial boundary value problems are used to prove local well-posedness and global existence. This type of system arises in mathematical models for cell processes. This is a joint work with Jeff Morgan at the University of Houston.

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PP1

AWM Workshop Lagrangian Data Assimilation and Its Application to Geophysical Fluid Flows

The goal of data assimilation is to combine knowledge of the underlying dynamical system and observations in order to estimate the current state of the system. Lagrangian data assimilation attempts to estimate the velocity field of a flow, given discrete observations of positions of passive drifters. In this poster I will present an overview of Lagrangian data assimilation in the context of fluid flows, including both traditional methods and a new hybrid" approach.

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PP1

Uniaxial Elongational Flow of a Thixotropic Yield Stress Fluid

The uniaxial elongational flow of a thixotropic yield stress fluid is studied with a viscoelastic constitutive model (Partially Extending strand Convection model, Larson, 1984) combined with a Newtonian solvent with no assumptions about the existence of a yield stress or thixotropy. The PEC model is based on molecular theory for highly branched polymers with side branches that get in the way of fully extending. A class of initial value problems with prescribed tensile stress is addressed. If the relaxation time is large, then there are two time scales which naturally emerge: a fast time scale for elastic deformation and flow, and a long time scale for small changes in the microstructure. The steady state curve for tensile stress vs elongation rate is non-monotone for a certain parameter range. The time-dependent solutions display an interplay of slow and fast dynamics.

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PP1

Pancreatic Beta Cells: Modeling the Interdependence of Intracellular Calcium and Insulin Release

Pancreatic beta cells secrete insulin, allowing the body to take up glucose for energy or storage. In diabetes, glucose is chronically elevated, contributing to cardiovascular disease. We study the interdependence of cell membrane potential and calcium oscillations used by beta cells to regulate insulin secretion. A theoretical model is developed, and regulatory candidates are tested in simulation to identify parameter values for data within the public domain.

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PP1

Inhibition of Mis-Regulated Nf-KB by Decoy Oligonucleotides: A Mathematical Implication

Nuclear factor-kB (NF-kB) is a transcription factor regulating the genes that control the cell proliferation and survival. Mis-regulated NF-kB proteins could lead to many types of human tumors. The inhibition of transcriptional activity of NF-kB by Decoy Oligonucleotides is an excellent approach to cure cancer. We model the related biochemical reactions in the single cell by Stochastic Master Equations. Our numerical results are consistent with the results of single-cell experimental studies of NF-kB gene regulatory networks and clinical studies.

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PP1

Eulerian Ergodic Partition Using the Backward Phase Flow Method

We develop an efficient Eulerian method to compute the ergodic partition for visualizing invariant sets in a continuous dynamical system. In particular, we apply the level set method and the phase flow method to determine the long time flow map. To determine the integral of an auxiliary function along particle trajectories, we propose to iteratively interpolate our flow maps. This method incorporates well with our Eulerian approach. We will also show some preliminary results to demonstrate the efficiency of the method.

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PP1

AWM Workshop Mesoscale Stochastic Modeling and Simulation of the Dynamics of Soft Gels: Transient Networks

Many polydisperse entangled materials such as concentrated wormlike micellar dispersions exhibit "slow" relaxation process compared with mono-exponential decay. The slow relaxation behavior is due to the distribution of energetic interactions between the entangled worms or other network components at the "mesoscale". In order to understand the dynamics of these fluids, and to avoid inaccurate closure relationships when constructing continuum-scale models, we model and simulate the evolution in the transient network deformation at the mesoscale.

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CT13 Abstracts

SIAM Conference on

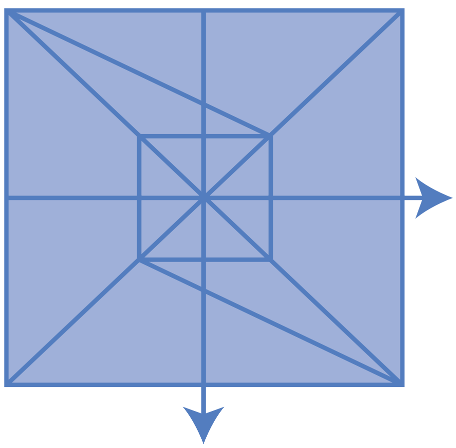

Figure courtesy Fabio Fagnani.

CONTROL & Its APPLICATIONS

July 8-10, 2013

Town and Country Resort & Convention Center

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IC1

Simplicial Nonlinear Principal Component Analysis

We present a new manifold learning algorithm that takes a set of data points lying on or near a lower dimensional manifold as input, possibly with noise, and outputs a simplicial complex that is the data and the manifold. We have implemented the algorithm in the case where the input data is on a two dimensional manifold in R3 and can be triangulated. We provide triangulations of data sets that fall on the surface of a torus, sphere, swiss roll, and creased sheet. We also discuss the theoretical justication of our algorithm.

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IC2

Fast Distributed Optimization Methods over Networks

The standard approach for designing distributed algorithms for optimization problems over networks rely on (sub)-gradient methods, but suffers from slow rate of convergence. In this talk, we present new distributed optimization algorithms with much faster rate of convergence. We first provide a completely asynchronous, distributed, and fast algorithm based on Alternating Direction Method of Multipliers for solving coupled convex optimization problems over networks. We then focus on a structured version of this problem where the local objective functions take an additive form with a differentiable and a nondifferentiable component and develop a distributed proximal gradient method.

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IC3

Control of Some Partial Differential Equations and Nonlinearity

In this talk, we survey some methods to study the controllability of some nonlinear partial differential equations when the nonlinearity plays an important role. This is for example the case when the linearized control system around the the equilibrium of interest is not controllable or if the nonlinearity is large at infinity and one looks for global results. Applications will be presented to various equations modeling fluid flows, as the Euler and the Navier-Stokes of incompressible fluids, the shallow water equations and the Korteweg-de Vries equations.

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IC4

Role Of Scientific Computation In Next Generation Innovation An Aerospace Perspective

For technologically mature industries or those with high barriers to change, innovation is a challenge. One low risk, low cost innovation path is to radically improve performance while minimizing change to existing infrastructure. In this presentation, a historical perspective on spacecraft optimal control is used to show how scientific computation can act as the enabler for next generation innovation. Real world examples will be presented where radical leaps in performance without altering spacecraft hardware or software has been achieved.

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SP1

AWM-SIAM Sonia Kovalevsky Lecture: Introduction to Radar Imaging

Radar imaging is a technology that has been developed, very successfully, within the engineering community during the last 50 years. Radar systems on satellites now make beautiful images of regions of our earth and of other planets such as Venus. One of the key components of this impressive technology is mathematics, and many of the open problems are mathematical ones. This lecture will explain, from first principles, some of the basics of radar and the mathematics involved in producing high-resolution radar images.

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SP2

2011 SICON Paper Prize Lecture #1: Feedback Stabilization of a Fluid-Structure Model

We study a system coupling the incompressible Navier-Stokes equations in a 2D rectangular domain with a damped Euler-Bernoulli beam equation, occupying the upper boundary of the fluid domain. Due to the deformation of the beam, the fluid domain depends on time. We prove that this system is exponentially stabilizable, locally about the null solution, with any prescribed decay rate, by a feedback control corresponding to a force term in the beam equation.

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SP3

2013 SICON Paper Prize Lecture #1: Gossip Coverage Control for Robotic Networks: Dynamical Systems on the Space of Partitions

Future applications in environmental monitoring, delivery of services and transportation of goods motivate the study of deployment and partitioning tasks for groups of autonomous mobile agents. These tasks may be achieved by recent coverage algorithms, based upon the classic methods by Lloyd. These algorithms however rely upon critical requirements on the communication network: information is exchanged synchronously among all agents and long-range communication is sometimes required. This work proposes novel coverage algorithms that require only gossip communication, i.e., asynchronous, pairwise, and possibly unreliable communication. Which robot pair communicates at any given time may be selected deterministically or randomly. A key innovative idea is describing coverage algorithms for robot deployment and environment partitioning as dynamical systems on a space of partitions. In other words, we study the evolution of the regions assigned to each agent rather than the evolution of the agents positions. The proposed gossip algorithms are shown to converge to centroidal Voronoi partitions under mild technical conditions.

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SP4

2011 SICON Paper Prize Lecture #2: Optimal Stopping Problem for Stochastic Differential Equations with Random Coefficients

An optimal stopping problem for stochastic differential equations with random coefficients is considered. Dynamic programming principle leads to a Hamiltion-Jacobi-Bellman equation which, for the current case, is a backward stochastic partial differential variational inequality (BSPDVI, for short) for the value function. Well-posedness of such a BSPDVI is established and a verification theorem is proved.

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SP5

2013 SICON Paper Prize Lecture #2: The Total s-Energy of a Multiagent System

We introduce the s-energy of a sequence of undirected graphs embedded in d-space. This generating function provides a new analytical lens on bidirectional agreement dynamics, which we use to bound the convergence rates of dynamical systems for synchronization, flocking, opinion dynamics, and social epistemology.

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SP6

The John von Neumann Lecture: What Sparsity and l1 Optimization Can Do For You

Sparsity and compressive sensing have had a tremendous impact in science, technology, medicine, imaging, machine learning and now, in solving multiscale problems in applied partial differential equations. l1 and related optimization solvers are a key tool in this area. The special nature of this functional allows for very fast solvers: l1 actually forgives and forgets errors in Bregman iterative methods. I will describe simple, fast algorithms and new applications ranging from sparse dynamics for PDE, new regularization paths for logistic regression and support vector machine to optimal data collection and hyperspectral image processing.

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SP7

SIAG/CST Prize Lecture - Feedback Control of Hybrid Dynamical Systems: from Cells to Power Networks

Hybrid systems have become prevalent when describing complex systems that mix continuous and impulsive dynamics. Continuous dynamics usually govern the evolution of the physical variables in a system, while impulsive (or discrete) behavior is typically due to discrete events and abrupt changes in the dynamics. Motivated by the lack of tools to rigorously study these systems, a mathematical framework and its associated tools for the analysis and synthesis of robust hybrid feedback control systems will be presented. The focus will be on asymptotic stability and invariance of sets. The tools will be exercised in applications, ranging from genetic networks to power systems.

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SP8

Past President's Address: Chebfun

Chebfun is a Matlab-based open-source software project for "numerical computing with functions" based on algorithms related to Chebyshev polynomials. In recent years developing Chebfun has been my main research activity, together with the closely linked project of writing the book *Approximation Theory and Approximation Practice* (SIAM 2013). This talk will present some highlights of the Chebfun endeavor and will be followed by a two-part Chebfun minisymposium.

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SP9

W. T. and Idalia Reid Prize in Mathematics Lecture: Solvability for Stochastic Control Problems

Some stochastic control problems for continuous time systems are described where optimal controls and optimal costs can be explicitly determined by a direct method. The applicability of this method is demonstrated by examples including the linear quadratic control problem with the system driven by an arbitrary noise process with continuous sample paths, a controlled Brownian motion in a symmetric space and the linear exponential quadratic Gaussian control problem. The problems for linear systems can be modified to allow for equations in an infinite dimensional Hilbert space that describe stochastic partial differential equations.

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SP10

I. E. Block Community Lecture: From Razor Clams to Robots: The Mathematics Behind Biologically Inspired Design

Many natural systems have evolved to perform certain tasks – climbing, sensing, swimming – as perfectly as possible within the limits set by the laws of physics. This observation can be used both to guide engineering design, and to gain insights into the form and function of biological systems. In this talk we will consider both of these themes in the context of crawling snails, digging clams and swimming microorganisms. We will discover how an analysis of the physical principles exploited by snails and clams leads to the development of novel robotic diggers and crawlers, and explore the role of mathematics in the design, control, and assessment of unconventional robotic systems.

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JP1

Applied and Computational Mathematics for Energy Efficient Systems

Recent advances in the development of sustainable energy sources have led to an emphasis on energy-supply technologies and the corresponding mathematical sciences needed for these technologies. However, energy efficient end-use technologies may also be viewed as an energy resource. Since buildings are responsible for 32% of energy consumption and for 26% of end-use C02 emissions, optimizing the efficiency of a whole building system is a "grand challenge control" problem with huge payoffs in the global energy sector. We discuss mathematical challenges and opportunities that occur in designing practical controllers for energy efficient buildings. Examples are presented to illustrate the ideas.

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CP1

Sparse Matrices and Decentralized Control: Theory and Algorithm

Vector spaces of sparse matrices appear naturally in the design of decentralized systems. In this context, one can think of the non-zero entries of the matrix as representing a communication link for a decentralized system. In spite of their pervasive presence, very little is known about the stability properties of these spaces, i.e. whether a given vector space of sparse matrices contains stable (Hurwitz) matrices. We provide in this talk a set of necessary and a set of sufficient conditions for the existence of stable matrices in a vector space of sparse matrices. We further prove global properties of the set of sparse matrix spaces that contain Hurwitz matrices. The conditions we exhibit are mostly graph theoretic and show the importance of Hamiltonian cycles in the study of stability from a graph theoretic perspective. Finally, we present polynomial time algorithms to generate sparse vector spaces that contains stable matrices.

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CP1

The Wasserstein Metric for Factor Analysis

We consider the problem of approximating a (nonnegative definite) covariance matrix by the sum of two structured covariances –one which is diagonal and one which has low-rank. Such an additive decomposition follows the dictum of factor analysis where linear relations are sought between variables corrupted by independent measurement noise. We use as distance the Wasserstein metric between their respective distributions (assumed Gaussian) which induces a metric between nonnegative definite matrices, in general. The rank-constraint renders the optimization non-convex. We propose alternating between optimization with respect to each of the two summands. Properties of these optimization problems and the performance of the approach are being analyzed.

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CP1

State of the Art Hifoo: H-Infinity Controller Optimization for Large and Sparse Systems

We present a new state of the art version of HIFOO, a MATLAB package for optimizing H_∞ and H_2 controllers for linear dynamical systems, supporting simultaneous multiple plant stabilization. Previous versions of HIFOO have generally been limited to smaller scale problems, due to the high asymptotic cost of computing the H_∞ norm of the transfer matrix. However, new sparse methods for computing the H_∞ norm allow HIFOO to extend efficiently to large and sparse systems.

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CP1

An All-at-Once Multigrid Method Applied to a

Stokes Control Problem

We are interested in an iterative solver for the Stokes control problem. The discretized optimality system is a large-scale and indefinite linear system. It depends on certain parameters: the discretization parameter (grid size) and problem parameters (like the regularization parameter). We are interested in fast iterative solvers which are robust in these parameters. In the talk we will propose an all-at-once multigrid method. We will sketch the ideas of a convergence proof.

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CP2

Optimal Control of Crop Irrigation Based on the Hamilton-Jacobi-Bellman Equation

This paper proposes a methodology to solve the optimal control of crop irrigation based on a dynamic model of plant growth in interaction with soil water reserve. We introduce the utility function corresponding to farming profit and derive the Hamilton-Jacobi-Bellman equation for the value function. It is solved with a backward finite-difference scheme proved to converge under proper CFL conditions. A few numerical test cases illustrate the resolution.

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CP2

A Chaotic Model for Bird Flocking

Pidgeons may be observed to flock in models that approximate the Lorenz Attractor. We would like to propose a model that is exactly observable and exactly controllable, given certain parameters, for a flock of birds. Applications of this model would be divided into those that are discrete, and those that are continuous. Discrete applications occur in graph theory and network theory.

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CP2

Optimal Bidding Strategies for Wind Power Producers with Meteorological Forecasts

The inherent variability in wind power generation and the related difficulty in predicting future generation profiles, raise major challenges to wind power integration into the electricity grid. In this work we study the problem of optimizing energy bids for an independent Wind Power Producer (WPP) taking part into a competitive electricity market. It is assumed that the WPP is subject to financial penalties for generation shortfall and surplus. An optimization procedure is devised to minimize this risk and maximize the expected profit of the seller. Specifically, each energy bid is computed by exploiting the forecast energy price for the day ahead market, the historical wind statistics at the plant site and the day-ahead wind forecasts provided by a meteorological service. We also examine and quantify the strategic role of an energy storage device in increasing reliability of bids and mitigating the financial risks of the WPP.

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CP3

Development and Improvement of Active Vehicle Safety Systems by Means of Smart Tire Technology

In this multidisciplinary project, an integrated vehicle control algorithm is developed which utilizes the novel smart tire concept to obtain information on system states. The control algorithm follows a two stage (main/servo) approach where an upper level controller decides on the stabilizing inputs and a lower level controller implements the inputs through actuator dynamics. The algorithms are validated through numerical analysis and provide substantial improvements in vehicle safety and performance.

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CP3

Adaptive Nonlinear Control for Electromagnetic Actuators

We study here the problem of robust 'soft-landing' control for electromagnetic actuators. The soft landing requires accurate control of the actuators moving element between two desired positions. We present here two nonlinear adaptive controllers to solve the problem of robust trajectory tracking for the moving element. The first controller is based on classical nonlinear adaptive technique. We show that this controller ensures bounded tracking errors of the reference trajectories and bounded estimation error of the uncertain parameters. Second, we present a controller based on the so-called Input-to-State Stability (ISS), merged with gradient descent estimation filters to estimate the uncertain parameters. We show that it ensures bounded tracking errors for bounded estimation errors, furthermore, due to the ISS results we conclude that the tracking errors bounds decrease as function of the estimation errors. We demonstrate the effectiveness of these controllers on a simulation example.

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CP3

A Passivity-Based Trajectory Tracking Controller for Robot Manipulators With Velocity Constraints

A stable control structure for trajectory tracking of robot manipulators subject to joint velocity constraints is proposed. The structure consists of a negative feedback connection, which includes the system dynamics, a tracking controller, and a non-linear passive controller. By using passivity and Lyapunov theory, asymptotic tracking with bounded velocities is proved for the closed-loop system. Simulation results are provided to show the effectiveness of the proposal.

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CP3

Reduced Order Observer Design for Structure and Motion Estimation

The problem of Structure and Motion Estimation in machine vision can be addressed by designing observers for dynamic systems. We propose and observer for feature point depth and camera linear velocity. The camera's angular velocity is assumed known. As well, we require two feature points with known displacement. Relative to previous work, we do not require linear acceleration measurements. The local exponential stability of the observer is proven using a converse Lyapunov theorem. We assume the camera motion satisfies a persistency of excitation condition and the linear acceleration is bounded and has finite energy.

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CP4

Design of Recursively Updated Reduced Order Dynamic Observers for Distributed Parameter Systems

A well-established approach to design controller and observer for distributed parameter systems is via model reduction, computing a reduced order model (ROM) using a combination of proper orthogonal decomposition (POD) variants with Galerkin method. The eigenvalues-eigenfunctions computation in this approach is based on the covariance matrix of a snapshots ensemble which usually are different from the eigenvalues and eigenfunctions of the PDE spatial operator. Thus, the ROM might be inaccurate when depicting the system dynamics at non-sampled regions of the state space leading to observers that require finely tuned observer gains. We propose a method to compute the PDE operator eigenfunctions based on empirical eigenfunctions obtained from adaptive POD. The controller/observer structure is then synthesized by combining a robust state controller with a recursively updated reduced order dynamic observer. The proposed method is illustrated on the integral form of the Kuramoto-Sivashinsky equation.

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CP4

Moderate Deviations Analysis for System Identification under Regular and Binary Observations

In this talk, we will investigate identification errors in a moderate deviations framework. This study provides a new perspective to understand the fundamental relationship between probabilistic errors and resources that represent data sizes in computational algorithms, sample sizes in statistical analysis, channel bandwidths in communications, etc. This relationship is derived by establishing the moderate deviations principle for regular and binary identification. Under some mild conditions, we obtain moderate deviations upper and lower bounds for regular and binary observations respectively. Numerical examples are provided to illustrate the theoretical results.

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CP4

Optimal Control of Particle Accelerators

The talk deals with the optimal control of particle accelerators by means of exterior magnetic fields. The forward problem is modeled by a nonlinearly coupled system consisting of the instationary Maxwell's equations, an ODE for the relativistic particle dynamics, and an additional elliptic equation for the scalar magnetic potential. The control enters the problem via the Dirichlet data in the elliptic equation. First-order necessary optimality conditions and preliminary numerical results are presented.

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CP5

A Monte Carlo Method for Optimal Portfolio Execution

We consider the problem of mean-variance optimal execution in markets with limited liquidity, as introduced in Almgren (2012). While most of the existing literature is concerned with deterministic strategies for the one-asset case, our paper deals with dynamic strategies for multi-asset portfolio executions. We propose a rolling horizon Monte Carlo scheme that allows real-time execution and any number of assets and stochastic drivers. We provide ample numerical experiments, which also shed new light on cases when deterministic strategies are optimal.

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CP5

Optimal Replication of Random Claims by Ordinary Integrals with Applications in Finance

By the classical Martingale Representation Theorem, replication of random vectors can be achieved via stochastic integrals or solutions of stochastic differential equations. We introduce a new approach to replication of random vectors via adapted differentiable processes generated by a controlled ordinary differential equation. We found that the solution of this replication problem exists and is not unique. This leads to a new optimal control problem: find a replicating process that is minimal in an integral norm. We found an explicit solution of this problem. Possible applications to portfolio selection problems and to bond pricing models are suggested.

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CP5

Recursive Optimal Control Problems for Regime-Switching Model

In this paper, we consider recursive optimal control problems for regime-switching model. The system is described by diffusion processes modulated by Markov chains while the recursive utility is represented by a kind of backward stochastic differential equations. First, we obtain the stochastic maximum principle for the optimal control. Then, we derive the recursive dynamic programming principle and prove that the value funcion is the unique viscosity solution of the generalized HJB equation system.

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CP6

Iterative Convolution Particle Filtering for Nonlinear Parameter Estimation and Data Assimilation with Application to Crop Yield Prediction

The complexity of plant growth models and the generally scarce experimental data make the application of conventional data assimilation techniques difficult. In this paper, we use the convolution particle filter and an iterative adaptation for parameter estimation. Both methods provide prior distributions for data assimilation sequentially performed by CPF in order to improve model prediction and to assess predictive uncertainty. The approach is evaluated for the LNAS model of sugar beet growth with real data.

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CP6

Parameter Estimation and Sensitivity Analysis in Ground Water Flow Equations

In previous works, we have proposed various methods for identification of the most significant parametric variations, and an optimization-based framework for estimation of distributed parameters. Combining both approaches, we use the Frchet derivative to determine the most significant (deterministic) parametric variations; this is used to generate a low order Karhunen-Loeve expansion of the unknown parameters specific storage and hydraulic conductivity. The expansion is used in the parameter identification problem, which is formulated as an infinite dimensional constrained optimization problem. The low order expansion allows us to estimate the infinite dimensional problem by a smooth, albeit high dimensional, deterministic optimization problem, the so-called finite noise problem, in the space of functions with bounded mixed derivatives. A power method and sensitivity equations are used to evaluate the most significant directions, and compute reduced representations of the operator.

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CP6

An Optimal Control Approach for An Hiv-Tb Co-Infection Model

We consider an HIV-TB co-infection model. To possibly reduce the latent and infectious sub-populations, we assume that detection rates of active TB individuals can be improved by applying more effective policies. We incorporate controls representing the fractions of active TB individuals among HIV^- and HIV^+ that are detected (as a result

of applying the suggested policy) and will be put under treatment. The optimal system is solved using efficient numerical techniques.

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CP7

Stability Analysis of a Controller/Observer for Input-Constrained DC-DC Boost Power Converters

In this paper, a new stability analysis of a known controller/observer for DC-DC boost converters is presented. The new analysis considers the overall closed–loop system, which includes the dynamics of the observation error as well as the dynamics of current and voltage error. This analysis relies in the stability theory of cascaded time-varying systems. In addition, two real–time experiments are shown, illustrating the robustness of the controller/observer.

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CP7

Homology of Lie Algebras and Evapotranspiration in Control of a Greenhouse

The following results are consequences of investigations considereing the interactions between the dynamics of a production greenhouse and the dynamics of the market for the greenhouse. It is had a three state variable dynamical system with three control variables, modelling a greenhouse. In this system is identified a Lie subalgebra containing a Heinsenberg subalgebra. With the structure constants of the Lie subalgebra is posible compute the associated evapotraspiration function of the greenhouse. Additionally is calculated the homology of the subalgebras. And in all the cases the Euler characteristic is null.

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CP7

Probabilistic Sensitivities for Fatigue Using Adjoint Methods

We present a new approach to develop methods and design tools to determine the sensitivity of the probability of failure of mechanically and thermally loaded hot gas components under the variation of design parameters and production-related deviations. This approach applied the adjoint methods to reduce the computational cost by computing these sensitivities.

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CP7

Discrete Active Disturbance Rejection Control for Chemical Processes

In this paper the discrete active disturbance rejection control (DADRC) is proposed for typical process control problems. In the DADRC framework, the external disturbances and internal dynamics associated with chemical processes are treated as the generalized disturbance to be estimated and compensated for in real time. By employing a discrete extended state observer for estimating the generalized disturbance, the DADRC provides a current estimate of states and therefore improves the performance of the closed-loop system.

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CP8

Mechanism Analysis of Robust Quantum Control

Robust Quantum Control is a novel field of research which studies how a quantum dynamical system can be coherently controlled to a target superposition of states in settings where noise is prevalent. In this work, we investigate how different types of disturbances on the control field's spectrum affect its *robustness*. Specifically, different-order state-to-state pathways associated with optimal fields' control mechanism are analyzed for their sensitivity to variations in the fields spectral bandwidth, phase and amplitude.

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CP8

Noether's Theorem for Control Problems on Time Scales

We obtain a generalization of Noether's theorem for the optimal control problems defined on time scales. This includes the discrete-time, the quantum, and the continuous/clasical optimal control as particular cases. The generalization involves a one-parameter family of smooth maps which depend also on the control and a Lagrangian which is invariant up to an addition of an exact delta differential. We apply our results to some concrete optimal control problems on an arbitrary time scale.

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CP8

Environment-Assisted One-Photon Coherent

Phase Control

A well established result, in the coherent-control-of-states community, is that control over relative product cross sections using one-photon excitation is not possible in the weak field regime. This result was stated under the assumption of unitary time evolution. Here we show that when the environment and its initial correlations with the system are taken into account, then one-photon phase control is possible. We also discuss how this environment-assisted process can be enhanced in the non-Markovian low temperature regime, specially for sub-Ohmic spectral densities.

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CP8

Quantum Noises Arising During the Quantum Implementation of an LTI System

Not all synthesized controllers correspond to physically meaningful quantum systems; additional quantum noises can be necessary for physical realizability. Given a state space system we give a result detailing the number of additional quantum noises required to implement it as a quantum system. We then give conditions including a numerical procedure for determining when it is possible to implement a transfer function as a quantum system with only the minimal number of additional quantum noises.

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CP9

Analyze of Synchronization Bifurcation Thank to Incremental Norm for a Class of Piecewise Smooth Systems

The synchronization phenomena occur in many domains: Life sciences, engineering sciences, In this talk, it is proposed to study the influence of small parameter variations on the trajectories synchronization for a class of piecewise smooth systems. First, the relied stability analysis is done with a well-known tools of incremental norm (see also contraction theory) and after the influence of infinitesimal perturbations on the initial conditions between to close trajectories is studied. For this, an abstract problem formulation is done in order to apply Lyapunov-Schmidt method and point out the bifurcation analysis.

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CP9

Periodic Control System Stabilization on Time Scales

The stabilization of periodic control systems using time scales is studied. Time scale is a model of time. The language of time scales seems to be an ideal tool to unify the continuous-time and the discrete-time theories. In this work we suggest an alternative way to solve stabilization problems. This method is based on a combination of the Lyapunov functions method with local controllability conditions. In many situations this method admits a rigorous mathematical justification and leads to effective numerical methods. Applications to mechanical problems are provided here.

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CP9

Necessary Conditions for Feedback Passivation of Nonaffine-in-Control Systems

It is well understood that an open-loop Lyapunov stable nonaffine-in-control nonlinear system can be asymptotically stabilized through feedback. *But stabilizing an open-loop unstable nonaffine system remains an open research question.* Toward this end, necessary conditions required to render a general open-loop unstable nonlinear system passive through static feedback are derived in this paper and it is shown that this is possible only if the system under consideration has relative degree one and is weakly minimum phase through an appropriate output definition. Unlike feedback passivation for affine-in-control nonlinear systems this result is not sufficient. The developments and the essential ideas of the paper are verified for a continuously stirred tank reactor.

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CP9

On Almost Lyapunov Functions

We study asymptotic stability properties of nonlinear systems in the presence of "almost" Lyapunov functions which decrease along solutions in a given region not globally but rather on the complement of a set of small volume. Nothing specific about the structure of this set is assumed besides an upper bound on its volume. We show that all solutions starting in the region approach a ball whose volume depends on the volume of the set where the Lyapunov function does not decrease, as well as on other system parameters. The result is established by a perturbation argument which compares a given system trajectory with nearby trajectories that lie entirely in the set where the Lyapunov function is known to decrease.

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CP10

A Noise Canceling Feedback Controller for the National Synchrotron Light Source II

The National Synchrotron Light Source II requires that disturbances to the beam at frequencies up to 500 Hz be cancelled. A feedback controller with 240 inputs (sensors) and 180 outputs (actuators) will do this. The controller uses singular value decomposition with Tikhonov regularization to convert the complete system into 90 single-input single-output systems with paired (fast but weak and slow but strong) actuators. A novel control scheme apportions the feedback between the two actuators.

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CP10

Application of The Fuzzy Gain Scheduling IMC-PID to The Power Plant

AbstractIn this paper, the use of a Fuzzy Gain Scheduling IMC-PID (FGS+IMC-PID) scheme has been presented based on fuzzy performance degree coefficient ? self-adjusting controller for the improvement of IMC-PID control. It is shown that the IMC-PID controller with the Fuzzy PID parameters Gain Scheduler provides satisfactory closed-loop responses with less overshoot and shorter rising times in case of both set point disturbance and the plant/model mismatch. Simulations are given, in which the proposed method is compared to other PID tuning methods (IMC, SPMG). The proposed scheme is suitable to implement in the complex process control system in power generation, since it does not demand significant computing resources. It has already been implemented through Function Code in many typical DCS (EDPU, XDPS, Ovation etc). Field application shows that the proposed is accurate enough. The industrial applications show that the scheme achieves better performance in specific load variation range. Keywords-IMC control, fuzzy self-adjusting, fuzzy gain scheduling, boiler-turbine coordinated control

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CP10

Stochastic Model and Simulation Results of Interactions Between Human Subjects and Air Traffic Control Simulator

Air Traffic Control Management requires constant attention and multi-tasking from human operators, which could invite human errors. In this setting, one wonders how such errors arise as operators interact with the machine to execute decisions. In this talk, a simple stochastic model including human reaction delays is discussed, and some experimental results collected from a game simulator in which subjects interact with a touch screen monitor are presented.

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CP11

A Parallel Implementation of Multiagent Coordination Optimization Algorithm

In this paper, a parallel Multiagent Coordination Optimization (MCO) algorithm is presented by introducing some MATLAB built-in function into MCO. This new MCO algorithm embeds cooperative swarm behavior of multiple agents into the update formula by sharing velocity and position information between neighbors to improve its performance. Numerical evaluation of the parallel MCO algorithm is provided in the paper by running the proposed algorithm on supercomputers, the optimal value and consuming time are compared with serial MCO and Particle Swarm Optimization (PSO) by solving several benchmark functions in the literature, respectively. Based on the simulation results, the performance of the parallel MCO is not only superb compared with PSO for solving many nonlinear, noncovex optimization problems, but also is of high efficiency by saving the computational time.

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CP11

Numerical Algorithms for Nonlinear Optimum Experimental Design Problems

We are interested in nonlinear optimum experimental design problems for dynamical systems. They result from statistical analysis of the solution of parameter estimation problems and can be regarded as non-standard optimal control problems in the sense that the objective depends on first-order derivatives of the states and exhibits a nonlinear coupling in time. We present reformulations of the problem and algorithms for efficient numerical treatment with the direct method of optimal control as well as numerical examples.

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CP11
ADI Iteration Parameters for CARE Application

Continuous low order Riccati equations (CARE) have been solved with Newton iteration involving ADI iterative solution of Lyapunov equations. The MATLAB EIGS program enables efficient evaluation of selected eigenvalues needed for determining good ADI iteration parameters. Eigenvalues clustered near the imaginary axis require special consideration. A new method for computing effective ADI iteration parameters will be described.

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CP11
Cheap Optimization of Experimental Designs

Our models of interest are algebraic and dynamical systems (DAEs, PDEs) that contain nature-given parameters p of unknown value and control functions/variables u/q. From measurements one infers the values of p. Due to errors in the measurements p is of uncertain nature. We discuss efficient techniques to minimize the uncertainty in p by optimizing over u/q and discuss algorithmic and conceptual challenges using the direct approach and automatic differentiation.

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CP12
Fixed Point Theory Approach to Exponential Convergence in LTV Continuous Time Consensus Dynamics with Delays

Distributed computation and multi-agent dynamics has been over the past years one of the most active research areas in the control community. In this work, we revisit the linear time varying consensus model in the presence of bounded communication delays. We prove exponential convergence of the autonomous agents to a common value under conditions related to the topology of the communication graph, the nature of the time-varying weights, and the dynamics of the undelayed system. We develop a Fixed Point Argument on an especially designed functional metric space. We consider the initial value problem.

$$\dot{x}_i(t) = \sum_j a_{ij}(t)(x_j(t-\tau) - x_i(t)), \qquad t \geq t_0 \qquad (1)$$

where $x_i(t) = \phi_i(t)$ for $t \in [t_0 - \tau, t_0]$ is the given initial data and τ is the positive and bounded delay constant. We also discuss the extensions to more asymmetrical versions with multiple delays.

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CP12
Saturation-tolerant Average Consensus with Controllable Rates of Convergence

The paper presents a distributed average consensus algorithm for multi-agent systems that enables individual agents to set their own rate of convergence. The algorithm has a two-time scale structure and is constructed using a singular perturbation approach. We provide a complete analysis of the proposed algorithm which includes rate of convergence of individual agents, effects of communication delays, robustness to changes in the network topology, implementation in discrete time, and robustness to saturation.

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CP12
Robustness and Performance Analysis of Cyclic Interconnected Dynamical Networks

The class of cyclic interconnected dynamical networks plays a crucial role in modeling of certain biochemical reaction networks. In this paper, we consider cyclic dynamical networks with loop topology and quantify bounds on various performance measures. First, we consider robustness of autonomous cyclic dynamical networks with respect to external stochastic disturbances. The $\mathcal{H}_{\in}$-norm of the system is used as a robustness index to measure the expected steady-state dispersion of the state of the entire network. In particular, we explicitly quantify how the robustness index depends on the properties of the underlying digraph of a cyclic network. Next, we consider a class of cyclic dynamical networks with control inputs. Examples of such cyclic networks include a class of interconnected dynamical networks with some specific autocatalytic structure, e.g., glycolysis pathway. We characterize fundamental limits on the ideal performance of such cyclic networks by obtaining lower bounds on the minimum L_2-gain disturbance attenuation. We show that how emergence of such fundamental limits result in essential tradeoffs between robustness and efficiency in cyclic networks.

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CP12

Pseudo-Rigid Formation Design for a Group of Unmanned Vehicles

The concept of pseudo-rigid formation (PRF) along with proposed design methodology is presented to deal with the path-planning problem for a group of unmanned vehicles. Comparing to the rigid formation, the PRF is allowed to rotate, stretch, or shear globally, specified by a homogenous deformation tensor, and the configuration space is then $R^3 \times SO(3)$. The overall design is composed of two parts. Firstly, the Rapidly-exploring Random Tree method equipped with some path-smoothing algorithms is applied to generate a proper path for the system center. The optimal deformation tensor is then found based on properly selected virtual potentials. The idea of Lennard-Jones potential in molecular dynamics is adopted to obtain the potentials for intra-collision between vehicles. According to the results of design examples, the proposed approach can be effectively used in a variety of environments to generate goal-attaining and collision-free paths for all vehicles.

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CP13

Necessary Conditions for Impulsive Optimal Control Problems

We study optimal control problems for systems that are governed by ordinary differential equations whose vector fields depend nonlinearly on the control and state variables, but linearly on the time derivatives of some components of the control. For a problem in the Mayer form and with final state constraints, we prove a maximum principle and higher-order necessary conditions in terms of the adjoint state and some Lie brackets of the involved vector fields.

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CP13

On a Singular Subarcs in Optimal Control Problem for a Simple Trolley-Type Model with Nonlinear Friction and Bounded Fuel Expenditure

We consider a problem on maximization of the distance traveled by a material point in the presence of a nonlinear friction and bounded thrust and fuel expenditure. Using the maximum principle we obtain the form of optimal control and establish conditions under which it includes a singular interval. We obtain these conditions by two ways. First, using the constructions of the maximum principle we obtain necessary and sufficient conditions of the optimal control to be of bang-bang form. Second, using the information about the form of optimal control and applying geometrical considerations we obtain sufficient conditions of the optimal control to have a bang-singular-bang form and verify that they are in accordance with the results above. We also demonstrate results of numerical experiments for different forms of the frictions function.

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CP13

A Variational Method Via Optimal Control

While optimal control theory is largely recognized as an extension of the classical calculus of variations, in this talk we argue that it also provides new variational approaches to boundary value problems. This is called the control variational method and it is based mainly on the Pontryagin maximum principle. In this presentation, we review the results established in the literature on the control variational method and its applications, in the last decade (including recent developments).

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CP13

On the Goh Second Order Conditions for Boundary Controls

We present second order necessary optimality conditions for the Mayer optimal control problem when the control set is a closed subset of R^m. In the absence of endpoint constraints, if an optimal control is singular, then, for almost every t, both the Goh and a generalized Legendre-Clebsch conditions hold true, eventually reducing to a subspace. In the presence of a smooth endpoint constraint, these conditions are satisfied whenever the Mayer problem is calm.

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CP14

Pulsed Feedback Defers Cellular Differentiation

Many cells use internal timers to autonomously defer differentiation for multiple cell cycles following a stimulus. How can cells build robust timers using genetic circuits? Bacillus subtilis cells respond to sudden stress with multiple rounds of replication before differentiating into spores. We show experimentally that a core pulsed positive genetic feedback loop controls this deferral. We further show mathematically that pulsed 'polyphasic' positive feedback may be especially robust, allowing cells to reliably set long deferral times.

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CP14

Are High Dimensional Spinal Neural Circuits Configured to Facilitate Rapid Learning?

We have modeled the major interneuronal circuits of the spinal cord, via which the brain controls limb movements. Despite the large number of controllable dimensions (about 400), simple coordinate descent models of motor learning tend to converge on good-enough solutions rather than getting stuck in poor local minima. It would appear that the density of such good-enough solutions rises as this dimensionality increases. Does this useful property generalize to a particular class of hyperspaces?

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CP14

Real-Time Optimal Control of the Euglycemic Clamp in Mice

The "gold standard' test for quantifying insulin resistance in diabetes research is known as the euglycemic hyperinsulinemic clamp. The protocol administers a variable glucose infusion in order to maintain a target plasma glucose concentration, given uncertain models of glucose metabolism; it is therefore a problem of real-time optimal control under uncertainty. We present a Bayesian framework that combines sequential Monte Carlo methods for parameter inference with model predictive control and sample-average approximation of the underlying optimization problem, and evaluate its performance with real data.

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CP14

Controlling Systemic Inflammation Using Nonlinear Model Predictive Control with State Estimation

We investigate the capability of a particle filter to enhance the success of a nonlinear model predictive control (NMPC) algorithm to find appropriate therapeutic strategies for improving outcomes in a highly nonlinear ordinary differential equations model of systemic inflammation. We compare with the results of previous work where the implementation of NMPC involved finding optimized dosing regimens for simulated patients, but with no robust state estimation. (Day et al., 2010 Math. Biosci. Eng. 7(4):739-763)

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CP15

Numerical Solution of Stochastic Regulator Problem with Nonlinear State Dynamics and Unbounded Terminal Condition

We consider nonlinear state dynamics and a quadratic terminal condition for a stochastic regulator problem. After providing theoretical results for the existence/uniqueness of the corresponding HJB equation, we solve the problem using a probabilistic approach through Markovian backward stochastic differential equations. We study the properties of the solutions, in particular, discuss the perturbed linear-quadratic regulator problems and provide some numerical examples.

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CP15

Stabilization of Galerkin Reduced Order Models (roms) for Lti Systems Using Controllers

Due to the computational cost of high-fidelity models (HFM), there is a growing interest in reduced order models (ROMs). Unfortunately, a ROM constructed using the POD/Galerkin approach is not guaranteed to preserve the stability of the HFM. This talk will describe an approach for stabilizing Galerkin ROMs for LTI systems using controllers. The stabilizing controller is computed using the theory of pole placement. The proposed ROM stabilization approach will be evaluated on several benchmark problems.

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CP15

High-Order Numerical Methods for Wave Equations with Van Der Pol Type Boundary Conditions

We develop high-order numerical methods for solving wave equations with van der Pol type nonlinear boundary conditions. Based on the wave reflection on the boundaries, we first solve the corresponding Riemann invariants by constructing two iterative mappings, and then, regarding the regularity of boundary conditions, propose two different high-order numerical approaches to the system. When the degree of regularity is high, we establish a sixth-order finite difference scheme. While for a low degree of regular-

ity, we provide another method by utilizing the high-order Gauss-Kronrod quadrature rule. Numerical experiments are performed to illustrate the proposed approaches.

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CP15

Solving the P-Laplacian Equation by Using Finite Elements Methods Leading to a Optimization Problem

A solution for the p-Laplacian equation using finite elements methods was introduced. It leads to an optimization problem that can be solved by simplex method. Besides, it was briefly discussed the solution of the non-Newtonian filtration equation.

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CP16

Functional Observers for Nonlinear Systems

The construction of a functional observer is well-motivated in many monitoring and control applications where full state information is not needed, but instead it is a given fuction of the states that needs to be estimated. The present paper will develop a theoretical formulation of the problem of designing functional observers for general nonlinear systems, in a way that directly extends linear Luenberger theory of functional observers. Notions of functional observer linearization will also be formulated, the objective being to achieve exactly linear error dynamics in transformed coordinates, and with prescribed rate of decay of the error. Necessary and sufficient conditions for the existence of a lower-order functional observer with linear dynamics and linear output map will be derived.

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CP16

Observer Based Fault Detection in Differential Algebraic Equations

Fault detection is an important part of most modern industrial systems and processes. One approach to fault detection is based on the use of observers. Many physical processes are most naturally modeled by differential algebraic equations. Recently there has been significant progress in the design of observers for complex differential algebraic equations. This paper examines the use of observers for fault detection in systems modeled by differential algebraic equations.

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CP16

Observer-Based Feedback Control of a Mathematical Model of Intimal Hyperplasia

A theoretical model of a potential treatment for intimal hyperplasia due to hemodialysis is proposed. This model consists of two parts. The first part is modeling the development of intimal hyperplasia as a diffusion process of muscle cells from the media to the lumen, for which the governing equation is a partial differential equation. The second part is designing an observer-based feedback controller to stabilize the equilibrium point of the system, corresponding to no intimal hyperplasia. Simulation results show that the intimal hyperplasia can be reduced to near zero in approximately 57 days of treatment.

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CP17

Tropical Optimization Problems: Solution Methods and Application Examples

Multidimensional optimization problems in the tropical mathematics setting are considered. The problems are to minimize (maximize) linear and nonlinear functionals defined on finite-dimensional semimodules over idempotent semifields, subject to constraints in the form of linear equations and inequalities. We outline known problems and discuss their solution methods. New unconstrained and constrained optimization problems are then examined and related exact solutions are given in a compact vector form. As an application, we present solutions of real-world problems in project scheduling and location analysis.

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CP17

On the Integer Max-Linear Programming Problem

Let $a \oplus b = \max(a, b)$ and $a \otimes b = a + b$ for $a, b \in \overline{R} = R \cup \{-\infty\}$ and extend these operations to matrices and vectors as in conventional algebra. The integer max-linear programming problem seeks to minimise or maximise $f^T \otimes x$ subject to the two sided system $A \otimes x \oplus c = B \otimes x \oplus d$ for integer x. Pseudopolynomial methods for solving this problem are known. We give a generic case where we can describe all feasible integer solutions, the optimal objective value and an optimal solution in strongly polynomial time.

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CP17

Equivalence Between Control Problems for Jump-Diffusions and Their Linear Programming Formulation

We prove that a class of control problems for jump-diffusion processes have the same optimal value as a linear programming problem for occupation measures as well as its dual formulation. The dual problem is strongly connected to the notion of subsolution of the HJB equation associated with the original control problem by means of a maximum principle for semicontinuous functions applicable to integro-partial differential equations.

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CP18

A Sufficient Condition for Stochastic Stability

The emergent behavior in natural/manmade systems can often be characterized by analyzing the limiting distribution of the governing Markov chain. While resistance trees have gained popularity as a computationally efficient way to characterize the stochastically stable states (i.e., support of the limiting distribution), this technique requires a graph theoretic analysis over a large state space. In this work, we derive sufficient conditions for stochastic stability which entails an analysis on a reduced state space.

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CP18

Conditions for the Existence of Constrained Optimal Policies for Discounted Markov Decision Processes

We consider a discrete-time Markov decision process with Borel state and action spaces. The criterion to be minimized is a total expected discounted cost subject to constraints on some discounted costs. By analyzing compactness issues on the space of strategic probability measures of the policies of the Markov decision process, we are able to establish the existence of a constrained optimal stationary policy, and we also prove the solvability of the corresponding linear programming problem. We prove such results under mild hypotheses on the control model.

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CP18

Multiresolution Stochastic Optimal Control

We propose an algorithm for the solution of continuous-time Markov decision processes with multiple time scales. Using singular perturbation methods we identify a sequence of models that are both smaller and are better conditioned. The proposed multiresolution algorithm uses the coarse model at each level of the hierarchy to compute a good initial approximation in the next level. We describe the convergence and complexity of the new algorithm and give numerical results.

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CP18

Optimal Control of Weakly Connected Markov Random Fields

We consider a spatially distributed finite state Markov decision process evolving over time with a Gibbs random field as its spatial structure. We suppose that the graph state space is partitioned into areas with internally strong but externally weak interactions. Modeling the weak interactions with a small scalar parameter ϵ, we obtain a singularly perturbed model of the Markov decision process. We discuss the asymptotic properties of the perturbed model as $\epsilon \to 0$.

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CP19

Risk-Averse Control with Time-Delay Compensation for Networked Stochastic Systems Subject to Communication Channel Constraints

This talk concerns with the formulation of a class of networked stochastic systems when the control loop is closed around a communication network. Specifically, all the signals exchanged from the linear dynamical controllers and the linear stochastic time-variant plants are therefore subjected to unknown yet constant time delays and additive white-noise communication channels. The novel approach to the risk-averse control problem is obtained to select optimal controllers for ordering uncertain prospects which are characterized by network induced time delays, communication channel constraints, and chi-square random performance measures.

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CP19

The Origin of Control of Complex Networks

The controllability of networks provides a new perspective to analyze large-scale, interconnected dynamical systems. We develop a theoretical framework based on the structure of the connective topology to determine the control profile of the network. Our analysis permits us to highlight the differences in control configurations between different types of networks. The composition of the control profile reveals the functional origin of control, which characterizes the flow of information, or state, through the network.

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CP19
Toward a Theory of Multi-Resolution Games

Multi-resolution decision-making is an important feature to achieve scalable and efficient control and computations in complex systems. In this paper, we establish a multi-resolution game-theoretic framework to model such decision processes in complex systems. The framework interconnects games of different resolutions through transition triggers and graphical models. The transition triggers are transition rules between games that are dependent on the outcome of the current game, while the graphical model captures the underlying structure of resolutions in the system. Based on Isaacs' tenet of transitions, we develop a games-in-games principle and use it to introduce new equilibrium solution concepts for this novel class of games. We apply the new analytical tools to study adaptive defense in network security through proactive mechanisms of diversity and randomization.

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CP20
Delay-Independent Stable Control Design for Linear Time Invariant (LTI) Systems with Multiple Uncertain Delays; Theory and Experiments

In many systems, delays are inevitable and can also be uncertain. When controlling such systems, it may therefore be beneficial to design a controller that renders the closed-loop system "delay independent stable'. In this talk, based on algebraic tools, we present a non-conservative framework for the control design on LTI systems with multiple uncertain delays, and application of this framework on a speed-regulation experiment in which uncertain delays arise in multiple communication/sensing channels.

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CP20
Multi-Agent Consensus Control with Communication Delay: Control Design and Application to a Three Nonholonomic Robot System

We focus on the consensus control of a three mobile-robot experimental system under communication delay, and demonstrate stable operation of consensus using a controller that is based on our recent results on network/graph structures, and Responsible Eigenvalue concept. Both theory behind control design, and experimental results in good agreement with theoretical predictions are presented.

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CP20
Applications of Reachable Sets to Driver Assistance Systems

Collision avoidance for driver assistance systems is an important and active field of research in car industry. A natural approach to define safety areas is to provide three reachable sets related to several situations: a separation assurance situation, a collision avoidance situation and a collision situation. Within this definitions reachable sets are computed for two scenarios with multiple initial states and several secure target constraints. Sensitivity analysis for the computed sets, with respect to perturbation of initial data, is given.

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CP21
Fast Optimal Control of Asymmetric Flow Field Flow Fractionation Processes

We present optimization problem for Asymmetric Flow Field Flow Fractionation, which is a widely used technique for segregation of two or more particles of submicron scale, according to their hydrodynamic radius. More specifically, we consider an optimal control problem for the focusing-injection stage of an Asymmetric Flow Field Flow Fractionation process, in which the distribution of particles suspended in a liquid needs to be controlled. We propose an objective functional for the concentration, based on the needs of our industrial partners. The state system is given by a convection-diffusion equation for the concentration, where the convective flow velocity is given by the solution of the quasi-stationary Stokes system, controlled on the boundary. For an optimization problem we use the sensitivities due to the special structure of the objective functional for this specific application and memory constraints.

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CP21

Existence and Approximate Controllability of Stochastic Semilinear Reaction Diffusion Systems

In this paper, we investigate the approximate controllability of an abstract model of stochastic semilinear reaction diffusion equation in Hilbert spaces. First, we prove the existence and uniqueness of mild solutions by using contraction mapping principle and formulated conditions which guarantee the approximate controllability of the main problem. Finally, the results are applied to semilinear damped stochastic wave equation and stochastic partial differential equations in modelling the structural damped vibrations of a string or beam.

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CP21

Exponential Stability for a One-Dimensional Thermoviscoelastic System with Dirichlet Boundaries

In this paper, we study the stability of a one-dimensional linear thermoviscoelastic equation with memory type for Dirichlet-Dirichlet boundary conditions. After a detail spectral analysis, we can show that there is a sequence of generalized eigenfunctions that forms a Riesz basis in the energy state space. Hence, the spectrum-determined growth condition holds and the exponential stability of the system can then be determined. This is a joint work with Jing Wang and Jun-Min Wang.

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CP22

Second-Order Sufficient Conditions for Optimal Control of Elastoplasticity

An optimal control problem governed by an elliptic variational inequality (VI) is considered. This VI models the static problem of infinitesimal elastoplasticity with hardening. It is well known that the control-to-state map associated to VIs is in general not Gateaux-differentiable. Thus standard techniques to derive optimality conditions cannot be employed. It can however be shown that the control-to-state operator associated to elastoplasticity is Bouligand differentiable. Based on this result, we establish second-order sufficient optimality conditions.

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CP22

Groebner Basis Computation of Feedback Control for Time Optimal State Transfer

The synthesis of time-optimal feedback control of a single input, continuous time, linear time invariant system with bounded inputs is considered. The target final state is not necessarily the origin of the state space. The switching surfaces corresponding to the bang-bang time-optimal control are first parameterized as functions of the $(n-1)$ switching instants. Then a Groebner basis based elimination algorithm is used to semi-algebraically represent the switching surfaces implicitly in terms of the state variables. These representations are used along with a nested switching logic to synthesize a time-optimal feedback control. As a natural extension, we also provide a semi-algebraic characterization of the set of all points reachable with constrained inputs.

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CP22

Lossless Convexification for a Class of Optimal Control Problems with Linear State Constraints

This paper presents lossless convexification for a class of finite horizon optimal control problems with non-convex control constraints and linear state constraints. Many practical problems take this form. The control set is relaxed to a convex set. Verifiable sufficient conditions are stated under which optimal solutions of the relaxed problem are also optimal solutions of the original problem, hence the term lossless convexification. A numerical example is presented to illustrate the approach.

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CP22

Subdifferential Analysis of Differential Inclusions Via Discretization

In differential inclusions, necessary optimality conditions identify potentially optimal paths, but do not show how to perturb paths to optimality. We estimate the subdifferential dependence of the optimal value in terms of the endpoints of the feasible paths by estimating the coderivative of the discretized reachable map. The discretized (nonsmooth) Euler-Lagrange and transversality conditions follow. Results for differential inclusions are inferred by pass-

ing to the limit.

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CP23

On Lie-Algebraic Reliable Stability Conditions for Multi-Channel Systems

Recently, Agrachev *et al* (in the paper Agrachev, A.A., Baryshnikov, Y. & Liberzon, D. (2012), "On robust Lie-algebraic stability conditions for switched linear systems," *Syst. Contr. Lett.,* **61** (2), 347–353) have presented a new sufficient condition for exponential stability of a switched system under an arbitrary switching using the Lie-brackets from a family of systems that generates the switched system. In this talk, we show that this condition may be formulated to characterize reliable stability conditions for a finite-dimensional generalized multi-channel system when some of the controllers (or subsystems) fail to operate in the way that they were originally intended to function. In particular, we make use of the Levi-Malcev decomposition theorem of Lie-algebra and provide a reliable stability condition for the multi-channel system when, *at an arbitrary time instant*, one of the controllers ceases to function due to a failure.

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CP23

Uniform Almost Sure Asymptotic Stabilization Problems by Adding Multi-Dimensional Wiener Processes

This paper derives necessary conditions for the origin of randomized systems to be uniformly asymptotically stable with probability one under randomization by multi-dimensional Wiener processes. First, we revisit randomization problems of deterministic systems by adding multi-dimensional Wiener processes. Next, we summarize Bardi and Cesaroni's stochastic Lyapunov functions are almost the same as Lyapunov functions for deterministic systems. Then, we derive the necessary conditions with remarkable discussions.

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CP23

The Purification and Bang-Bang Principles in Infinite Dimensions: Additional Characterizations of the Saturation Property

We present a synthetic treatment of several results of consequence in mathematical economics and the theory of optimal control and of statistical decision-making: the Lyapunov theorem, the DWW theorem, the convexity of the integral and distribution of a multifunction, the bang-bang principle and the purification principle. Under a coherent hypothesis on the measure space, that of saturation, we demonstrate not only that these fundamental results are valid in separable Banach spaces, but also that they are equivalent to each other and their validity implies that the underlying probability space must necessarily be saturated. We apply our main result to variational problems with integral constraints. A novelty here is to incorporate infinite-dimensional constraints into the problem in a general manner. To this end, the standard relaxation technique is employed. First, we prove that the existence of optimal solutions to the relaxed variational problem without any assumption on probability spaces. Next, we purify the optimal relaxed controls by applying the purification principle in saturated probability spaces to derive the optimal control functions for the original variational problem. Finally, we present a result on relaxed controls with infinite-dimensional constraints that improves the density result of the finite-dimensional setting.

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CP23

Stabilization of the Korteweg De Vries Equation

The Korteweg de Vries (KdV) Equation is one of the most important partial differential equations in applied mathematics and, starting with shallow water waves in the 1800's, is still finding applications in many areas of physics and mathematics. Our recent work on long waves for swirling flow through a pipe has shed light on previously unknown properties of the solutions of initial–boundary value problems for the KdV equation. This talk will report on some of these results.

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CP24

Accessing the Role of Communication Link and Node Robustness in Interconnected Systems Via Eigenvalue Sensitivity

Communication networks provide a larger flexibility for the control design of interconnected systems by allowing the information exchange between the local controllers and may improve the performance of the overall system. However, it is still not well understood how significant the role of a communication link is for improving the performance and how the network structure influences the robustness of the system. We first show via numerical example that certain communication links play important role in improving the systems performance. Next, using eigenvalue sensitivity analysis, we characterize those links for interconnected systems consisting of scalar identical subsystems with ring and uniform extended star physical topologies. We further study the relation between network robustness and the physical topology when one of the nodes is perturbed and observe that there exists a trade-off between designing an interconnected system with high robustness and low communication cost.

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CP24

The Method of Moments for Optimal Switching Topology Networks

In this work, it is presented a semidefinite relaxation to solve the optimal control problem of switching topology networks based on the method of moments. This method is the transformation of a non-convex optimal control problem into an equivalence problem with linear and convex structure. An equivalence convex formulation more appropriated to be solved by high-performance numerical computing tools. Finally, a numerical example is presented to illustrate the effectiveness of the proposed approach.

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CP24

On Multi-Input Controllable Linear Systems Under Unknown Periodic DoS Jamming Attacks

In this paper, we study remotely controlled and observed multi-input controllable continuous linear systems, subject to periodic Denial-of-Service (DoS) jamming attacks. We first design a control and triggering strategy provenly capable of beating any *partially known* jammer via properly placing the closed-loop poles. Building on it, we then present an algorithm that is able to guarantee the system stability under *unknown* jamming attacks of this class. The functionality of this algorithm is also theoretically proven.

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MS1

Stabilization of Wave PDE/nonlinear ODE Cascades

The problem of compensation of input delays in nonlinear systems was recently solved using predictor feedback. Yet, the problem of compensation of more complex input dynamics in nonlinear systems has remained, heretofore, untackled. In this paper we consider nonlinear systems with a wave partial differential equation (PDE) in the actuation path, and we design an explicit feedback law that compensates the wave actuator dynamics. We study stability of the closed-loop system with the aid of a Lyapunov functional that we construct by introducing two novel infinite-dimensional backstepping transformations of the actuator state. We also present a numerical example that illustrates the effectiveness of the proposed control design.

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MS1

Stabilizability of Piezoelectric Beams with Magnetic Effects

A PDE model for a controlled piezoelectric beam that includes magnetic effects is studied, with current and also voltage control. Both models are shown to be well-posed. Next, we investigate stabilizability. A current controlled beam, is shown to be strongly stabilizable by a single electrical feedback controller. In the case of voltage controlled beam we obtain exponential stabilizability with a single electrical feedback controller, provided that the parameters satisfy certain conditions. This is different from the usual model that neglects magnetic effects.

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MS1

A Control Theoretic Approach to Low Reynolds Number Swimming

We consider a couplked ODE's–PDE's system modeling a class of low Reynolds number swimmers (which can be seen as simplified models of cilliated microorganisms). Within this model, the form of the swimmer does not change, the propelling mechanism consisting in tangential displacements of the material points of swimmer's boundary. The main theoretical results assert the exact controllability of the swimmer for prolate spheroidal shapes. In the same case, we provide theoretical bounds of the efficiency and we perform numerical simulations.

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MS1

Finite Dimensional Attractors in Flow-Structure Interactions

We consider a von Karman plate with a delayed feedback force. Due to physical considerations we study the model *without* inertial terms, producing a loss of compactness - critical for studying attractors. We show asymptotic smoothness and quasi-stability the associated dynamical system; this approach is novel in this context. We apply our result to a flow-plate interaction and demonstrate the existence of a finite-dimensional, compact attractor for the plate dynamics. This is done by utilizing *hidden* dissipation from the flow.

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MS2

Convergence Analysis for Discretized Control-State Constrained Optimal Control Problems with Controls of Bounded Variation

We study convergence properties of discretized optimal control problems with ordinary differential equations and mixed control-state constraints. Under suitable consistency and stability assumptions a convergence rate of order $1/p$ of the discretized control to the continuous control is established in the L^p-norm. Throughout it is assumed that the optimal control is of bounded variation. The convergence proof exploits the reformulation of first order necessary optimality conditions as nonsmooth equations.

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MS2

A-priori Monotonicity Properties of Minimizers and Applications to existence Results for Noncoercive Variational Problems

In this talk an a-priori monotonicity property of minimizers of one-dimensional variational problems is discussed. Such a property allows to obtain a refined version of the classical DuBois-Reymond necessary conditions, with a limitation on the constant appearing in the condition, besides to some existence and non-existence results of the minimum for non-convex, non-coercive variational problems.

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MS2

Optimal Control of the Sweeping Process Generated by Moving Convex Polyhedra

This talk is based on the joint work in progress with Rene Henrion (Weierstrass Institute at Berlin, Germany) and Nguyen Dinh Hoang (Tan Tao University, Vietnam). We study a new class of optimal control problems of the sweeping (Moreau) process governed by differential inclusions described by the normal cone mapping to moving polyhedral convex sets in finite-dimensional spaces. The main attention is paid to deriving necessary optimality conditions for such unbounded discontinuous differential inclusions. This is done by developing the method of discrete approximations and employing appropriate tools of second-order variational analysis and generalized differentiation.

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MS2

Properties of Control Systems with Mixed Constraints

We report on relevant properties of some control systems with mixed constraints. The main question we address is whether state trajectories for control systems paired with mixed constraints (in the form of equalities and inequalities and even more general) are precisely the feasible solutions of a differential inclusions. This is of relevance since it allows the application of well known results for differential inclusion like compactness of trajectories, relaxation, generalized Filippov selections and existence of solution. Although some if not all of our results seem to be known we present and prove them here in a concise and clear way that may be helpful in different set-ups.

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MS3

Approximating Non-Stationary Hamiltonians for Minimum-Time Problems in Dynamic Environments

An algorithm for solving a class of non-stationary Hamilton-Jacobi (HJ) equations is described, which can be broken into piecewise-stationary Hamiltonians. Taking advantage of the inherent causality of the problem, an improved version of the algorithm using is shown to dramatically reduce the computation time. Examples of time-optimal path planning problems with dynamic environments are shown.

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MS3

Can Single-Pass Methods Solve Every Hamilton-Jacobi Equation?

The use of single-pass methods (like, e.g., the Fast Marching method) has become popular in the solution of some nonlinear hyperbolic PDEs. The prototype of these equations is the eikonal equation, where the methods can be applied saving CPU time and possibly memory allocation. Naturally one would like to extend this approach to other Hamilton-Jacobi equations. Is it possible? If not, where the limit should be set? In this talk we try to answer those questions analyzing several test cases.

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MS3

Causality as a Source of Efficiency

In this talk we will discuss the connections between label-setting/correcting methods on graphs and a variety of non-iterative numerical methods for static Hamilton-Jacobi-Bellman PDEs arising in optimal control problems. We will discuss the accuracy/efficiency implications of anisotropy as well as the challenges associated with the lack of small-time-controllability. We will also compare the types of causal structure present in finite-horizon, infinite-horizon, exit-time, optimal-stopping, and stochastic-switching problems.

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MS3

Efficient Methods for Finite-Horizon Optimal Control

Time-dependent Hamilton-Jacobi PDEs naturally arise in many applications including fixed-horizon optimal control problems. Numerical methods for these equations are typically based on using an explicit time discretization, resulting in fairly restrictive CFL stability condition on the allowable time-steps. The conventional wisdom states that time-implicit methods for non-linear evolutive PDEs are not a viable alternative for two reasons: (a) their lower accuracy and (b) their higher computational cost. In this talk we will use linear advection equations and non-linear time-dependent Eikonal PDEs to investigate whether the above arguments are universally valid.

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MS4

On Participation Factors for Nonlinear Systems

In this talk, we combine between recent definitions given by Prof. Abed for participation factors of linear systems and Poincare normal forms to propose new definitions for participation factors for nonlinear systems.

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MS4

Control of Discrete-Time Nonlinear Systems with Long Non-Increasing Time-Varying Delays on the Input

We consider general discrete-time nonlinear systems with long non-increasing time-varying input delays, and design a nonlinear predictor feedback controller to compensate the input delays. The input delay is modeled by a first-order partial difference equation (PdE) and a discrete-time backstepping transformation is employed to construct a Lyapunov function. Based on the Lyapunov function, the global asymptotic stability is achieved even for the high-growth nonlinear systems. This approach is also applied to linear time-invariant (LTI) systems and the global exponential stability is achieved in the presence of long non-increasing time-varying input delays,. Our design approach is illustrated by a numerical example for a nonlinear plant with high-growth nonlinearity.

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MS4

Asymptotic Stabilization for Feedforward Systems with Delayed Feedbacks

We solve a state feedback stabilization problem for a large class of time-varying feedforward systems with a pointwise input delay. We use a time-varying change of coordinates and Lyapunov-Krasovskii functionals. The result applies for any constant delay, and provides controllers of arbitrarily small amplitude and input-to-state stability under actuator errors. We illustrate our work in a tracking problem for a model for high level formation flight of unmanned air vehicles.

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MS4

Control of Fluid Flows in Channels

We investigate the finite-time boundary stabilization of a 1-D first order quasilinear hyperbolic system of diagonal form on [0,1]. The dynamics of both boundary controls are governed by a finite-time stable ODE. The solutions of the closed-loop system issuing from small initial data in Lip([0,1]) are shown to exist for all times and to reach the null equilibrium state in finite time. A finite-time stabilization is also shown to occur when using only one boundary control. The above strategy is then applied to the Saint-Venant system for the regulation of water flows in a canal with one or two boundary controls.

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MS5
Optimal Control of Discrete Systems

In this talk we discuss a geometric approach to the analysis of discrete optimal control problems. We show how various mechanical problems can be formulated naturally in this setting and we show how the approach leads to integrators for optimal control problems and mechanical systems in Lie groups and homogeneous spaces.

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MS5
Distributed Line Search Algorithms for Multi-Agent Systems

This paper considers multi-agent systems seeking to optimize an aggregate objective function. We assume the gradient of this function is distributed, meaning that each agent can compute its corresponding partial derivative with state information about its neighbors and itself. In such scenarios, the discrete-time implementation of gradient descent poses the fundamental challenge of determining appropriate agent stepsizes that guarantee the monotonic evolution of the objective function. We provide distributed anytime algorithmic solutions for this problem.

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MS5
The Standard Parts Problem and Quantization in Optimal Control Problems

Mobile robotic vehicles are increasingly well endowed with high performance sensing capabilities. This motivates research into whether high performance biomimetic motion control can be achieved. Using a large archive of flight data from field observations of bats, research has been conducted to design motion control feedback laws that use a variety of sensing modalities to approximately interpolate stored animal trajectories.

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MS5
Controlled Lagrangians and Stabilization of Discrete Spacecraft with Rotor

The method of controlled Lagrangians for discrete mechanical systems is extended to the problem of stabilization of the rotations of a spacecraft with a symmetric rotor about its intermediate inertia axis. The Moser–Veselov discretization is used to obtain the discrete dynamics of the system. Stabilization conditions for the continuous model and its discretization are compared. It is shown that stability of the discrete system is sufficient for stability of its continuous counterpart.

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MS6
Efficiency and Risk Tradeoffs in the Smart Grid

Real-time demand response has been postulated as the solution to the intermittency problem created by renewable generation. The proposed market architecture is simple, namely, consumers react directly to spot market prices in order to fulfill their demands. This mechanism creates a closed loop system between price and demand that has implications on efficiency, demand and price volatility, and risk of demand spikes. In this talk, we first present an analysis of this closed loop system for homogeneous consumers and highlight the tradeoffs between market efficiency and demand and price volatility. We demonstrate that this analysis is consistent with the volatility of current spot market prices, suggesting the presence of internal trading and hedging in the market. Then, we present an abstracted framework to analyze the tradeoffs between efficiency and risk for heterogeneous consumers when demands are shiftable. In this context, we expand the market mechanism to study the impact of coordination on such a tradeoff. For decisions based on real-time prices, we compare the statistics of the aggregate electricity demand process induced by non-cooperative and cooperative load shifting schemes. We show that although the non-cooperative load-shifting scheme leads to an efficiency loss (otherwise known as the price of anarchy), the scheme has a smaller tail probability of the aggregate unshiftable demand distribution. This tail distribution is important as it corresponds to rare and undesirable demand spikes. In contrast, the cooperative scheme achieves higher efficiency at the cost of a higher probability of demand spikes. Such instances highlight the role of the market mechanisms in striking a balance between efficiency and risk in real-time markets.

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MS6

Opportunities and Challenges in Smart Grid Controls

Smart electric grid is a vision of the future where the electric power network is integrated with a communications, computation, and control system to achieve certain objectives: customer participation, integration of all generation and storage options, new markets and operations, power quality, asset optimization and efficiency, self healing, and resiliency. In this talk, we will present a few key challenges from a controls perspective whose solution will contribute to the achievement of this vision.

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MS6

Challenges in Electricity Smart Grids of the Future

Risk-limiting dispatch is formulated as the optimal solution to a multi-stage, stochastic decision problem. The operator purchases forward energy and reserve capacity over a block of time, based on the available information, including demand and renewable power. The accumulated energy blocks must at each t match the net demand. The expected cost is the sum of the costs of the energy and reserve capacity and the risk from mismatch between net demand and supply.

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MS6

Integration of Active Demand in Electricity Distribution Grids

The key idea behind the concept of Active Demand is that end users play an active role in the electricity grid, adjusting their consumption patterns to mitigate the effects of the introduction of renewables and energy dynamic pricing policies. Participation in AD schemes generally takes place through aggregation of consumers represented by a new subject, the aggregator, whose main objective is to value the load profile flexibility of individuals. The objective of this talk is to outline the main problems related to this scenario, where new players operate in the energy market and in the grid, consumers show a dynamic behavior, the transmission and distribution operators face new hard tasks with new opportunities to ensure safe operation of the grid.

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MS7

Zero-Sum Game Between a Controller and a Discretionary Stopper

We consider a stochastic differential equation that is controlled by means of an additive finite-variation process. A singular stochastic controller, who is a minimiser, determines this finite-variation process while a discretionary stopper, who is a maximiser, chooses a stopping time at which the game terminates. We consider two closely related games that are differentiated by whether the controller or the stopper has a first-move advantage. The games' performance indices involve a running payoff as well as a terminal payoff and penalize control effort expenditure. We derive a set of variational inequalities that can fully characterize the games' value functions as well as yield Markovian optimal strategies. In particular, we derive the explicit solutions to two special cases and we show that, in general, the games' value functions fail to be C1. The non-uniqueness of the optimal strategy is an interesting feature of the game in which the controller has the first-move advantage. This is a joint work with Robert S. Simon and Mihail Zervos.

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MS7

Optimal Ergodic Control with Minimum Variance

This work concerns controlled Markov processes with either continuous or discrete time parameter. We give conditions for the existence of control policies that maximize the long-run average reward and which, in addition, minimize the limiting average variance. To this end, a key intermediate step is to show that this variance is a constant independent of the initial state. Our results have applications in ergodic control problems,and also in adaptive control problems which depend on unknown parameters.

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MS7

Pathwise Convergence Rates for Numerical Solutions of Markovian Switching Stochastic Differential Equations

We develop numerical approximation algorithms for solutions of SDEs with Markovian switching. The existing numerical algorithms all use a discrete-time Markov chain for the approximation of the continuous-time Markov chain. In contrast, we generate the continuous-time Markov chain directly, and then use its skeleton process in the approximation algorithm. Focusing on weak approximation, we take a re-embedding approach, and define the approximation and the solution to the switching SDE on the same space. In our approximation, we use a sequence of i.i.d. random variables in lieu of Brownian increments. By virtue of the strong invariance principle, we ascertain rates of convergence in the pathwise sense for the weak approximation scheme.

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MS7

Some New Perspectives About Certain Singular Control Problems

This work investigates a singular stochastic control problem for a multi-dimensional regime-switching diffusion process confined in an unbounded domain. The objective is to maximize the total expected discounted rewards from exerting the singular control. Such a formulation stems from application areas such as optimal harvesting multiple species and optimal dividends payments schemes in random environments. With the aid of weak dynamic programming principle, we characterize the value function to be the unique constrained viscosity solution of a certain system of coupled nonlinear quasi-variational inequalities. Several examples are analyzed in details to demonstrate the main results.

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MS8

Introduction to Biological Reactor Models with a View on Differential Flatness Properties

Various simple models of biological reactors are reviewed, with biomass, substrate and product concentrations, with an emphasis on their differential flatness properties. We in particular establish that quotients of biomasses over substrate appear to be flat outputs for the investigated models, independently of the growth rate function model. This property yields a differential parametrization of the system in terms of the flat output.

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MS8

Stabilization of the Chemostat with Delayed Sampled Measurements

The classical model of the chemostat with one substrate, one species and a Haldane type growth rate function is considered. The input substrate concentration is supposed to be constant and the dilution rate is considered as the control. The problem of globally asymptotically stabilizing a positive equilibrium point of this system in the case where the measured concentrations are delayed and piecewise constant with a piecewise constant control is addressed. The result relies on the introduction of a dynamic extension of a new type.

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MS8

Interval Observers with Delays for Biological Reactors

We propose constructions of interval observers for families of systems with a point-wise delay. First, we develop a new type of interval observer for a general class of systems which present distributed delay terms. Second, we take advantage of this design to design an exponentially stable interval observer for a nonlinear biotechnological model.

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MS8

Chemostat Stabilisation Through Delayed Buffering

Global stabilization of the chemostat model under non-monotonic growth rate has received great attention from the control community that have provided different feedback strategies. Recently, it has been shown that a structure of buffered chemostat can exhibit a global stability without control. Analogously, we investigate the benefit of a delay in the input flow rate for enlarging the attraction basin of the stable positive equilibrium.

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MS9

Reduced-Order Modeling and Control of Aquatic

Vehicles Exploiting Biomimetic Vortex Shedding

Marine animals often exploit high-dimensional hydrodynamics associated with vortex shedding and wake-body interactions for self-propulsion and maneuvering. Biologically inspired aquatic vehicles are often intended to harness similar phenomena using relatively low-dimensional actuation. This talk will address the realization of reduced-order models for localized vortex shedding and wake dynamics and the nonlinear control of underactuated aquatic vehicles that vary their surface geometries or inertial properties for locomotion.

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MS9

Distributed Estimation of Ocean Internal Waves Via Relative Sensing

We present strategies for estimating the time varying flow field generated by an ocean internal wave, by determining the physical wave parameters which define the flow's dynamics. The algorithm runs on a group of Lagrangian drifters which receive local, relative inter-drogue distance measurements. Our technical analysis establishes correctness guarantees under noiseless measurements, characterizes the parameter robustness with respect to noisy measurements, and identifies a strategy for fusing parameter estimates.

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MS9

Gliding Robotic Fish: A Highly Maneuverable and Energy-Efficient Platform for Aquatic Sensing

We present a novel type of underwater robots, gliding robotic fish, which represent a hybrid of robotic fish and underwater gliders. A gliding robotic fish is capable of fin-actuated swimming and buoyancy-driven gliding, and is thus highly maneuverable and energy-efficient, showing great promise in long-duration monitoring of aquatic environments. Its maneuvering in 3D space presents intriguing and challenging questions in dynamic modeling and control, which are discussed in this talk.

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MS9

Robustness of Adaptive Control under Time Delays for Three-Dimensional Curve Tracking

We analyze the robustness of a class of controllers that enable three-dimensional curve tracking of free moving particles. Using Lyapunov-Krasovskii functionals and robustly forwardly invariant sets, we prove input-to-state stability under predictable tolerance and safety bounds that guarantee robustness under control uncertainty, input delays, and polygonal state constraints, and adaptive tracking and identification of unknown control gains. This can provide certified performance when the results are applied to marine robotic controllers.

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MS10

Control of Pde Systems with Delayed Actuators

In this paper we discuss a boundary control problem for parabolic partial differential equations where the control input is the output to a dynamic actuator modeled by a delay differential equation. The combined system leads to an infinite dimensional retarded delay differential equation. We discuss well-posedness issues and develop approximations for addressing the LQR control problem. Applications to control of energy efficient systems are presented and examples are given to illustrate the method.

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MS10

Synchronizing Controllers for Second Order Distributed Parameter Systems

We consider the synchronization control of second order infinite dimensional systems. The objective is to design controllers that guarantee agreement between the position and velocity states of N identical second order systems. To enforce synchronization, the controller structure involves coupling terms consisting of the pairwise difference of both position and velocity states. Possible improvements of the agreement amongst the states of each of the systems are considered and compared to the case of noninteracting controllers. Extensions to synchronizing controllers for the case of partial connectivity are discussed. Extensive numerical studies are included to provide a further insight on the effects of synchronizing control of second order infinite dimensional systems.

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MS10

Balanced POD Model Reduction Algorithms for Parabolic PDE Systems with Unbounded Input and Output Operators

Balanced POD is a data-based model reduction algorithm that has been widely used for linearized fluid flows and other linear parabolic PDE systems with inputs and outputs. We consider balanced POD algorithms for such systems when the input and output operators are unbounded, as can occur when control actuators and sensors are located on the boundary of the physical domain. We discuss computational challenges, modified algorithms, and convergence theory.

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MS10

An Optimal Design Problem Involving Helmholtz Equation in Multi-Layered Materials

The photovoltaic devices based on layers of thin-film of organic semiconducting materials offer a potentially low-cost and versatile alternative to the conventional silicon solar panels. Efforts are made in the optimized device design based on mathematical models of the propagation of incident solar radiation and the resulting generation and diffusion of exciton through the heterojunction cell. Basic questions of potential performance gain achievable by optimizing the thickness of the semiconducting organic layers and optical lens capping the device are investigated. The computation based global optimization convincingly indicates that the highest achievable device performance cannot be modified solely by the lens design. Validation of mathematical models and the computational optimization experiments are also presented.

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MS11

Regularity Issues for the Control of the Bilinear Schrödinger Equation

The dynamics of a closed quantum system submitted to an external field can be modelled, in a first approximation, by a bilinear Schrödinger equation. Many difficulties arise from this modelling that involves both unbounded operators on the state and a non-linearity in the control. The aim of this talk is to provide a survey of recent results on this topic, with a special focus on how geometric control techniques allow to overcome the deep regularity issues inherent to these systems.

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MS11

Stabilization of Nonlinear Systems Modeled by Partial Differential Equations: Some Tools and Some Open Problems

In this talk we survey some tools to stabilize nonlinear systems modeled by partial differential equations. Various examples will be presented. They include Euler equations of incompressible fluids, Korteweg de Vries equations, shallow water equations, beam equations, porous media equations. However, as we will show, there are many open problems, especially for rapid stabilization.

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MS11

Sparse Control of Social Dynamics for Large Groups

Social dynamics of large group of autonomous agents is of interest to various applications, such as animal groups, crowd dynamics, markets etc. An important self-organization phenomenon is convergence to consensus, which can emerge naturally or achieved by controls. We present results using controls which are sparse in the number of controlled agents and switchings in time.

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MS11

Control of Multi-scale Models for Crowd Interaction

We first present the multi-scale version for the Cucker-Smale model, that describes the interaction of crowds and large groups. We discuss the interest and difficulties of control of this system, focusing in particular to the problem of driving the crowd to consensus. We then present results of controllability to consensus: we show that techniques of sparse controllability for a finite number of agents can be adapted to the multi-scale model.

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MS12

Equivalent Convexification in Optimal Control

An approach to convexifying non-convex optimal control problems with integral objective functionals is discussed. A basis is a probabilistic relaxation of the system we extend the systems states to probability measures. The originally given system equation is then transformed into a linear integral equation involving mathematical expectations of the systems states and velocities, and the resulting relaxed optimal control problem turns into a problem of convex optimization under linear equality type constraints. Generally, the optimal value in the relaxed problem is smaller than that in the original one (in which the objective functional is minimized). We provide conditions sufficient for the equivalency of the relaxed problem to the original one and describe a convergent successive solution approximation method.

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MS12

Harmonic Analysis and Optimal Control: Analytic Representation of Solutions of Riccati Matrix Equations

Classical methods of feedback stabilization of linear control systems via optimal control are based on algebraic matrix Riccati equations. In this talk we use methods of harmonic analysis and optimal control to obtain formulas for analytical representation of solutions of algebraic matrix Riccati equations. These analytical formulas are stated in terms of matrix transfer functions of the original linear control system. Since matrix transfer functions can be measured and evaluated in many applications these analytical formulas can be used for design of stabilizing feedback without a need in an identification of linear system model in space-time domain. We also use this approach to obtain analytical representation formulas for solutions of differential matrix Riccati equations. These results demonstrate how linear harmonic analysis can be exploited to find formulas for solutions of some nontrivial nonlinear differential equations.

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MS12

Optimal Control Strategies for Reducing the Number of Active Infected Individuals with Tuberculosis

We consider an optimal control model for tuberculosis (TB) with reinfection and postexposure interventions. The control functions alter the fraction of early and persistent latent TB individuals under treatment with anti-TB drugs. Our aim is to study how these control measures can maximize the reduction in the number of active infected individuals while minimizing the cost associated with their implementation. This objective is attained through theoretical computations and numerical simulations.

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MS12

Rauch and Bonnet-Myers Type Comparison Theorems for Optimal Control Problems

We will give estimates for the number of conjugate points along extremals of quite general optimal control problems in terms of certain state-feedback invariants of the corresponding control systems. These estimates generalize the classical Rauch and Bonnet-Myers comparison theorems in Riemannian Geometry. The application of these results in sub-Riemannian Geometry will be discussed.

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MS13

Controllability and Conditionally Stationary Measures

It is well known that controllability properties of nonlinear control systems may give information on the supports of stationary measures for associated random dynamical systems, where the control is replaced by an appropriate random input or noise. More precisely, under ergodicity assumptions for the noise, the supports of the stationary measures are determined by the invariant control sets. This is valid for systems in continuous time and in discrete time. For the latter class of systems, this presentation transfers this correspondence to conditionally stationary measures and an associated notion of relatively invariant control sets. Relatively invariant control sets are subsets of complete approximate controllability which are maximal with respect to a given open subset W of the state space. It turns out that the system can leave such a set only, if it also leaves W. We think of W as the world in which the system lives or the safe region which must not be left. Necessary and sufficient conditions for the existence of relatively invariant control sets are given, and it is shown that support of every conditionally stationary measure is a relatively invariant control set. Using a perturbation approach, sufficient conditions for the existence of conditionally stationary measures are given.

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MS13

On Control and Random Dynamical Systems in Reproducing Kernel Hilbert Spaces

We introduce a data-based approach to estimating key quantities which arise in the study of nonlinear control systems and random nonlinear dynamical systems. Our approach hinges on the observation that much of the existing linear theory may be readily extended to nonlinear systems - with a reasonable expectation of success - once the nonlinear system has been mapped into a high or infinite dimensional Reproducing Kernel Hilbert Space. In particular, we develop computable, non-parametric estimators approximating controllability and observability energy functions for nonlinear systems, and study the ellipsoids they induce. It is then shown that the controllability energy estimator provides a key means for approximating the invariant measure of an ergodic, stochastically forced nonlinear system. We also apply this approach to the problem of model reduction of nonlinear control systems. In all cases the relevant quantities are estimated from simulated or observed data. These results collectively argue that there is a reasonable passage from linear dynamical systems theory to a data-based nonlinear dynamical systems theory through reproducing kernel Hilbert spaces. This is joint work with J. Bouvrie (MIT).

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MS13

Junction Conditions for Hamilton-Jacobi-Bellman System on Multi-Domains

A system of Hamilton-Jacobi-Bellman (HJB) equations on a partition of R^d with interfaces is considered. While the notion of viscosity is by now well known, the question of uniqueness of solution, when the Hamiltonian is discontinuous, remains an important issue. We investigate the junction conditions on the interfaces, the region of discontinuity of the Hamiltonian, to provide an existence and uniqueness result for a general class of HJB equations.

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MS14

On the Coexistence of Synchronization and Chaos

In this talk we report on numerical experiments showing empirical evidence for synchronization between two coupled systems even though small parameter averaging theory shows that there is no periodic solution having a period near the apparent period suggested by the numerical simulations. We relate this to simple feedback mechanisms associated with phase and amplitude control in engineering and biological models.

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MS14

Polyhedral Subdivisions of Piecewise Affine Functions and Applications

This talk discusses the geometry of a Lipschitz piecewise affine (PA) function and its applications. It is known in the theory of piecewise differentiable functions that such a function admits a polyhedral subdivision of a Euclidean space. Motivated by robust and sensitivity analysis, we establish an important relation between matrix-vector pairs of candidate affine functions of a PA function by exploring polyhedral subdivision geometry. Its implications in dynamical Lipschitz piecewise affine systems will be discussed.

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MS14

Dynamics and Control of a Chain Pendulum on a Cart

The global Euler-Lagrange equations are derived for a chain pendulum, a serial connection of n rigid links connected by spherical joints, that is attached to a rigid cart. The configuration of the system is in $(S^2)^n \times R^2$. We examine the rich structure of the uncontrolled system dynamics, and provide the corresponding controllability criterion. We also show that any equilibrium can be asymptotically stabilized by using a PD type controller, and provide numerical examples.

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MS14

Contact Geometry of Optimal Control Problems

I will show that contact geometry, particularly a projectivized cotangent bundle and the standard contact structure on it, provides a natural geometric setting for optimal control problems. Specifically, the necessary condition for optimality of the Pontryagin maximum principle is formulated as a contact Hamiltonian system on the projectivized cotangent bundle. I will also talk about a simple application of contact transformations to optimal control problems and its relation to the transversality conditions.

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MS15

Optimal Low Thrust Orbit Transfer with Eclipsing

It is well known that computing the trajectory of a spacecraft moving from one orbit to another, can be formulated as an optimal control problem. New spacecraft that utilize solar electric propulsion systems introduce challenging computational hurdles for numerical optimization techniques. First, because the thrust is very low, the resulting trajectories are very long. Second, the solar electric propulsion systems provide no thrust when the spacecraft passes through a shadow, and the number and location of these regions cannot be determined a priori. Third, nonlinear gravitational perturbations caused by oblate earth and n-body effects exacerbate the sensitivity of the solution. This talk will discuss the issues encountered when solving such real world applications.

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MS15

NLP Sensitivity with Direct Transcription: A Strategy to Incorporate Moving Finite Elements Within DAE Optimization

A direct transcription strategy with moving finite elements is proposed with features that include direct location of control breakpoints, and termination criteria based on a constant Hamiltonian and DAE approximation error constraints. The resulting problem formulation is decomposed into an inner NLP problem, a fixed element direct transcription, and an outer NLP, which adjusts finite elements based on above termination criteria. The two layer approach is implemented with the IPOPT NLP and sIPOPT sensitivity codes.

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MS15

Direct Transcription Solution of Optimal Control Problems with State and Control Delays

Direct transcription is a popular approach used to numerically solve many optimal control problems in industry. This talk will discuss progress on the development of an industrial grade direct transcription optimal control software package that works with processes modeled by differential algebraic equations and for which there are state and control delays. The inclusion of DAE formulations greatly increases the types of delayed problems that can be solved. It also raises difficulties in determining a priori if a problem is formulated correctly for its numerical solution. The analysis of problems with control delays is also complicated by the fact that even with constant delays sometimes the theory for uniform grids is not applicable to nonuniform grids and nonuniform grids are essential in the consideration of large, complex problems. Theory, numerical algorithms, and computational examples will be presented.

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MS15

Numerical Solution of State-Inequality Constrained Optimal Control Problems Using Collocation at Legendre-Gauss and Legende-Gauss-Radau Points

It is known that state inequality path constraints in optimal control problems may produce discontinuities in the costate that are difficult to approximate numerically. One approach to overcoming this computational issue is to reformulate the first-order optimality conditions of the continuous-time problem to produce continuous costates. In this presentation we will discuss a method for costate estimation of state-inequality constrained optimal control problems using orthogonal collocation at Legendre-Gauss-Radau (LGR) and Legendre-Gauss (LG) points. In the case of LGR points, the differentiation matrix associated with the costate estimate is singular, whereas the differentiation matrix associated with the state inequality constraint multipliers is invertible. Furthermore, it is shown that the inverse of this differentiation matrix is an integration matrix. In the case of LG points, it is shown that the formulation of the optimal control problem must be modified to so that the path constraint is enforced at the boundaries of the domain where the dynamics are not collocated.

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MS15

Convergence of Hp Pseudospectral Method for Unconstrained Optimal Control

A convergence theory is established for approximations of unconstrained optimal control problems based on a Radau collocation scheme where both the polynomial degree on each mesh interval and the number of mesh intervals can be freely chosen. Under assumptions of coercivity and smoothness, we show that this hp-scheme has a local minimizer and corresponding transformed adjoint multiplier that converge in the sup-norm to a local minimizer and costate of the optimal control problem. The accuracy is improved either by increasing the degree of the polynomial within mesh intervals or by refining the mesh.

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MS16

Optimal Control for Deformable Image Registration

Image registration is an important component for many medical image analysis methods. It is a means to establish spatial correspondences within or across subjects and a fundamental building block for example for atlas-building. This talk will discuss the optimal control viewpoint of deformable image registration with a particular emphasis on adjoint solution methods and numerical solutions.

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MS16

Dynamical Systems Framework for Anomaly Detection in Videos

Behavior analysis in crowded scenarios is a challenging computer vision problem due to vast diversity and complexity. Recently, new insights have been obtained by treating crowd motion as a fluid flow driven by optical flow in images. In this talk we present geometric and statistical concepts (Lagrangian Coherent Structures and Almost Invariant Sets) from dynamical systems theory to analyze such time dependent flow fields, and demonstrate their applications in crowd segmentation and anomalous behavior detection.

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MS16

Convex Relaxations of Semi-Algebraic Optimization Problems Arising in Systems Identification and Machine Learning

This talks discusses convex relaxations of semi-algebraic optimization problems arising in three closely related fields: identification and model (in)validation of switched systems, manifold embedding of dynamic data and semi-supervised learning. As we will show in this talk, all of these problems are equivalent to minimizing the rank of a matrix that depends polynomially on the data. While in principle this is a hard non-convex problem, the use of moments based ideas allows for reducing it to a structured principal component decomposition: decomposing a matrix as a sum of structured low-rank and sparse components. In turn, this problem can be very efficiently solved performing only a sequence of singular value decomposition and thresholding operations.

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MS16

Optimal Mass Transport as a Shape Metric for Visual Tracking

We will describe an observer framework for visual tracking that explicitly uses shape information on the space of planar curves. Each planar shape is modeled as a pdf via the uniform distribution on its boundary. This allows us to use optimal mass transport to compare the shapes employing a Luenberger type observer. Here distance is measured via the associated Wasserstein 2-metric. Optimal mass transport will be used in conjunction with previously developed geometric observer approach.

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MS17

Iterative Dual Approach for Stochastic Control with Information Relaxation

We use the information relaxation technique to develop value- and policy- iterative methods to solve discrete time stochastic control problems. In each iteration, we can obtain both upper and lower bounds for the true values-to-go. Both methods ensure a convergence to the optimal solution within finite iterations. Some financial applications are discussed in this talk to show numerical efficiency.

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MS17

Stochastic Maximum Principle for Controlled Systems Driven by Fractional Brownian Motions

We obtain a maximum principle for stochastic control problem of general controlled stochastic differential systems driven by fractional Brownian motions. To arrive at the necessary conditon for the optimal control, a type of backward stochastic differential equation driven by both fractional Brownian motion and the corresponding underlying standard Brownian motion is introduced. In addition to this backward equation, the maximum principle also involves the Malliavin derivatives. This is joint work with professor Yaozhong Hu and Dr. Jian Song.

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MS17

Stochastic Differential Games for Fully Coupled FBSDEs with Jumps

This paper is concerned with stochastic differential games (SDGs) defined through fully coupled forward-backward stochastic differential equations (FBSDEs) which are governed by Brownian motion and Poisson random measure. First we give some basic estimates for fully coupled FBSDEs with jumps under the monotonic condition. We also prove the well-posedness and regularity results for fully coupled FBSDEs with jumps on the small time interval under a Lipschitz condition (where the Lipschitz constants of $\sigma,\ h$ with respect to $z,\ k$ are small enough) and a linear growth condition. For SDGs, the upper and the lower value functions are defined by the controlled fully coupled FBSDEs with jumps. Using a new transformation, we prove that the upper and the lower value functions are deterministic. Then, after establishing the dynamic programming principle for the upper and the lower value functions of this SDGs, we prove that the upper and the lower value functions are the viscosity solutions to the associated upper and the lower Hamilton-Jacobi-Bellman-Isaacs (HJBI) equations, respectively. Furthermore, for a special case (when $\sigma,\ h$ do not depend on $y,\ z,\ k$), under the Isaacs' condition, we get the existence of the value of the game. It's based on a common work with Qingmeng Wei (School of Mathematics, Shandong University, Jinan 250100, P. R. China).

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MS17

Viscosity Solution to Path-Dependent Bellman Equations

In this paper we study the optimal stochastic control problem for a path-dependent stochastic system. The associated Bellman equation from dynamic programming principle is a path-dependent fully nonlinear partial differential equation of second order. A novel notion of viscosity solutions is introduced. Using functional Itô calculus initiated by Dupire, the value functional of the stochastic optimal control problem is characterized as the unique viscosity solution to the associated path-dependent HJB equation.

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MS18

Optimal Design Techniques for Distributed Parameter Systems

We formulate an optimal design problem for the selection of best states to observe and optimal sampling times and locations for parameter estimation or inverse problems involving complex nonlinear nonlinear ordinary or partial differential systems. An iterative algorithm for implementation of the resulting methodology is proposed. Its use and efficacy is illustrated on three applied problems of practical interest: (i) dynamic models of HIV progression, (ii) modeling of the Calvin cycle in plant metabolism and growth, and (iii) optimal design of source detection and location in 3D problems.

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MS18

Randomize-then-Optimize: A Monte Carlo Method for Estimation and Uncertainty Quantification in Inverse Problems

Many classical methods for solving inverse problems require the solution of an optimization problem, e.g., maximum likelihood (ML) and maximum a posterior (MAP) estimation. Uncertainty quantification (UQ) in these settings is typically performed using either classical Gaussian theory or simulation techniques such as Markov chain Monte Carlo. In this talk, we present a Monte Carlo method for estimation and UQ that we call randomize-then-optimize (RTO). Rather than creating a Markov chain, RTO makes use of the optimization algorithm used in the ML or MAP estimation to sample from the probability density of interest.

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MS18

Parameter Subset Selction for Complex Models

Increasing demands on accuracy of models require comprehensive models involving large numbers of parameters. In particular because of limited data available for parameter estimation in general it is impossible to identify all parameters of a complex model. Consequently we need systematic methods in order to select those parameters which can be identified with sufficient accuracy. The different variants of parameter subset selection provide such methods. In the talk we discuss several concepts of parameter subset.

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MS18

Bayesian Techniques for Model Calibration and Quantification of Model Errors

Measurement and model errors produce uncertainty in model parameters estimated through least squares fits to data. In many cases, model errors are neglected during model calibration. However, this can yield nonphysical parameter values for applications in which the effects of unmodeled dynamics are significant. In this presentation, we will discuss the use of autoregressive (AR) processes to quantify model errors. Densities for the model and AR process parameters are constructed using delayed rejection adaptive Metropolis (DRAM) algorithms. We illustrate aspects of the framework in the context of distributed structural models with highly nonlinear parameter dependencies.

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MS19

Heat and Schroedinger Equations on Degenerate Riemannian Manifolds

On a two dimensional manifold, we consider the optimal control problem $\dot{x} = u_1 F_1 + u_2 F_2$, $\int_0^T (u_1^2 + u2^2) dt \rightarrow$min, where $F_1 = (1, 0)$ and $F_2 = (0, x^\alpha)$ and initial and final points are fixed. The solutions of this problem are the minimizing geodesics for the generalized Riemannian metric $g = dx_1^2 + x_1^{-2\alpha} dx_2^2$. The corresponding Laplace-Beltrami operator present some diverging first order terms: $\Delta = \partial_{x_1}^2 + |x_1|^{2\alpha} \partial_{x_2}^2 - \frac{\alpha}{x_1} \partial_{x_1}$. In this talk we discuss the self-adjointness and the stochastic completeness of this operator.

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MS19

Perturbation Methods and Heat Kernel Asymptotics

Hypoelliptic heat kernels on sub-Riemannian manifolds have been shown to encode geometric information, just as their elliptic counterparts on Riemannian manifolds. Some of this geometric information (e.g., the sub-Riemannian distance function) can be recovered from the short-time behaviour of the hypoelliptic heat kernel. In principle, one could try to "read off" the sub-Riemannian geometry from the short-time behaviour of the heat kernel. In reality however, the computation of closed-form expressions for heat kernels for general sub-riemannian geometries is a major challenge, and, in general, no such closed-form expressions can be expected. In this talk, we will show how perturbation theory ideas can help in recovering the short-time behaviour of the heat kernel, even when no closed-form expression for it is known.

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MS19

Optimally Swimming Stokesian Robots

We study self propelled stokesian robots composed of assemblies of balls, in dimensions 2 and 3, and prove that they are able to control their position and orientation. This is a result of controllability, and its proof relies on applying Chow's theorem in an analytic framework, similarly to what has been done in [F.Alouges, A.DeSimone,and A.Lefebvre,J. Nonlinear Sci., 18(3), 2008] for an axisymmetric system swimming along the axis of symmetry. However, we simplify drastically the analyticity result and apply it to a situation where more complex swimmers move either in a plane or in three-dimensional space, hence experiencing also rotations. We then focus our attention on energetically optimal strokes, which we are able to compute numerically. Some examples of computed optimal strokes are discussed in detail.

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MS19

Common Features of Diffusions in the Sub-Riemannian and Riemannian Contexts

Despite being a "degenerate" geometry, some aspects of sub-Riemannian geometry mirror more familiar situations. We give two examples. First, we explain how to extend a technique, introduced by Molchanov, for studying the small-time asymptotics of the heat kernel at the cut locus from the Riemannian to the sub-Riemannian context. Second (time permitting), we discuss a class of diffusions arising from submanifolds (of Riemannian manifolds) and sub-Riemannian structures that provides a common stochastic framework for both geometric situations.

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MS20

Serial and Parallel Hybrid Two-Scale Methods for Eikonal Equations

The Eikonal equation has recently found its way into a number of applications, which has prompted the development of many efficient numerical algorithms. In this talk I will survey some of the state-of-the-art methods for the Eikonal equation, and then proceed to a hybrid two-scale method called the Heap-Cell Method (HCM). I will then present a parallelization of the HCM and explore its compatibility with second-order methods.

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MS20

Fast Replanning and Any-Angle Planning

In this talk, we give an overview of our research on any-angle path planning methods and on incremental path replanning methods. In robotics or video games, one often discretizes continuous terrain into grids with blocked and unblocked cells and replans when the terrain or one's knowledge of the terrain changes. Any-angle path planning methods propagate information along grid edges (to achieve small runtimes) but without constraining the paths to grid edges (to find short paths). Incremental path replanning methods solve sequences of similar path planning problems faster than individual searches from scratch by reusing information from previous searches to speed up the current search.

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MS20

The Monotone Acceptance Ordered Upwind Method: A Causal Algorithm for Minimum Time / Cost Optimal Control.

The Monotone Acceptance Ordered Upwind Method (MAOUM) solves the same class of problems as the Ordered Upwind Method of Sethian & Vladimirsky [SINUM 2003], but does so with a precomputed stencil that can adapt to local grid spacing. Consequently, MAOUM is able to guarantee that nodes are accepted in order of their value and performs considerably better than the older algorithm when significant grid refinement is used to improve approximation quality for problems with nonsmooth solutions.

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MS20

A Fast Marching Dynamic Replanning Method for Mobile Robots

Weighted-Region Planning can formalize the problem of finding optimal paths for a robot subject to various objectives and constraints. Roboticists commonly use graph search methods in such settings, but this produces discretization artefacts in the plans. Smoothing and interpolation methods have thus been proposed, but most of them fail to address the root cause. However, Fast Marching can be leveraged to properly address this issue. The E* planner builds on fast marching, and extends it with the efficient replanning mechanism of D*. It can thus efficiently cope with scenarios for interweaved planning and control, where the underlying cost distribution frequently changes. This talk will present the E* planner and discuss some open questions: whether focusing heuristics can be added, how to develop rigorous proofs for the fully dynamic case, and how to extend it to non-holonomic and anisotropic cases.

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MS21

Pontryagin Principles for Infinite-Horizon Constrained Problems

We present several results on the necessary conditions and sufficient conditions of optimality for infinite-horizon and discrete-time optimal control problems when the admissible processes ought to satisfy several kinds of constraints.

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MS21

Multiobjective Optimal Control over Infinite Horizon

Multiobjective optimal control problems in the discrete-time case and infinite horizon framework are studied for systems governed by difference equations or difference inequations with or without constraints. Pontryagin Maximum Principles are established in the weak form and in the strong form. Alternative theorems and results due to Philippe Michel are among the tools used to prove our theorems. We also give sufficient conditions of optimality.

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MS21

Spectral Methods for the Solution of Infinite-Horizon Optimal Control Problems

We consider a class of infinite horizon optimal control problems in Lagrange form involving the Lebesgue integral in the objective. This special class of problems arises in the theory of economic growth and in processes where the time T is an exponentially distributed random variable.

The problem is formulated as optimization problem in Hilbert Spaces. It reads as follows: Minimize the functional

$$J(x,u) = \int_0^\infty r(t,x(t),u(t))\nu(t)dt$$

subject to all pairs $(x,u) \in W_2^n(^+,\nu) \times L_2^r(^+,\nu)$, satisfying state equations

$$\dot{x}(t) = f(t,x(t),u(t))\,,$$

control restrictions

$$u(t) \in U, \quad U \in Comp\,(R^r) \setminus \{\emptyset\},$$

and initial conditions

$$x(0) = x_0.$$

The remarkable on this statement is the choice of Weighted Sobolev- and Weighted Lebesgue spaces as state and control spaces respectively. The function ν is a density function. These considerations give us the possibility to extend the admissible set and simultaneously to be sure that the adjoint variable belongs to a Hilbert space. For the class of problems proposed, we can proof an existence result as well as Pontryagins Maximum Principle. Considering

$$\langle x,y\rangle := \int_0^\infty x(t)^T y(t)\nu(t)dt$$

as scalar product in the weighted Lebesgue - space a spectral method is developed to construct a numerical scheme for the solution of the problem.

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MS22

Structure-Preserving Model Reduction for Nonlinear Port-Hamiltonian Systems

This work proposes a structure and stability preserving model reduction approach for large-scale input-output nonlinear Port-Hamiltonian systems with an a-priori error bound. Two techniques for constructing reduced-order bases are considered: Proper orthogonal decomposition (POD) and a quasi-optimal H2 model reduction. The nonlinear term is reduced efficiently using an extension of the discrete empirical interpolation method (DEIM). Numerical tests are shown using a nonlinear ladder network and a Toda lattice model with exponential interactions.

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MS22

Volterra Series Interpolation Framework for Model Reduction of Bilinear Systems

The interpolatory model reduction methods for bilinear systems so far have focused on interpolating the homogenous subsystems individually. In this talk, we introduce a new framework where multi-point interpolation is performed on the underlying full Volterra series. This, in turn, has a direct connection to optimal-H2 model reduction of bilinear systems and allows us to produce optimal-H2 approximants by solving only regular Sylvester equations.

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MS22

Systematic Goal-Oriented Reduced-Order Models for Complex Systems

Many grand challenge problems at the frontier of computational science, such as flow control and optimization problems, require repeated numerical simulations of large-scale dynamical systems. To alleviate the tremendous computational cost demanded in these applications, the proper orthogonal decomposition (POD) method has been widely utilized. However, its accuracy and efficiency in a highly nonlinear system are severely limited due to the intrinsic features of the POD method. In this talk, we propose a systematic, goal-oriented model reduction methodology for general complex systems. Its mathematical theory and numerical behavior will also be discussed.

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MS22

Reduced Order Controllers for Boussinesq Equations with a Nonlinear Observer

Reduced-order models are essential in the design of feedback control laws for complex distributed parameter systems. It is well known that reduced models must capture the input-output behavior of the underlying system. This is also true when nonlinear observers are incorporated. However, we add additional constraints that the reduced models provide accurate representations of the distributed nature of the controller. This approach is demonstrated on a control problem arising in the development of energy efficient buildings.

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MS23

Strategies for Distributed Information Acquisition and Propagation in Networks

The talk will define the concept of an “interaction density” that describes the way information at each node is related to the information held at each other node of a network. This density is useful in defining information theoretic quantities such as *conditional entropy*, *mutual information*, and *directed information* may be studied. I shall describe the role of the concepts in understanding connection patterns that optimize information transfer in various networks.

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MS23

Stochastic Surveillance Strategies for Spatial Quickest Detection

We design robotic surveillance strategies for the quickest detection of anomalies taking place in an environment of interest. From a set of predefined regions in the environment, a team of autonomous vehicles collects noisy observations, which a control center processes. The overall objective is to minimize detection delay while maintaining the false alarm rate below a desired threshold. We present joint anomaly detection algorithms for the control center and vehicle routing policies.

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MS23
Smart Realizations of Sparse Transfer Matrices

Abstract not available.

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MS23
Solving a Linear Equation Across a Network

This talk describes a very simple distributed algorithm for solving a system of linear equations of the form $A_i x = b_i, \quad i = 1, 2, \ldots, n$ where A_i is a $m_i \times m$ matrix and b_i is an m_i vector. The system is recursively solved by n agents assuming that agent i knows only the pair (A_i, b_i) and its neighbors' current estimates of a solution. All n estimates converge exponentially fast to a solution to the system provided only that the time-varying graph $\mathbf{G(t)}$ characterizing neighbor relations is strongly connected for all t.

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MS24
Discrete Time Linear Quadratic Control with Arbitrary Correlated Noise

A control problem for a discrete time linear stochastic system with a general correlated noise process and a cost functional that is quadratic in the state and the control is solved. An optimal control is given explicitly as the sum of the well known linear feedback control for the associated deterministic linear-quadratic control problem and the prediction of the response of a system to the future noise process. The optimal cost is also given explicitly.

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MS24
Stability of Numerical Methods for Jump Diffusion Systems

This work is devoted to stability analysis of numerical solutions for jump diffusions and jump diffusions with Markovian switching. Different from the existing treatment of Euler-Maurayama methods for solutions of stochastic differential equations, we use techniques from stochastic approximation. We analyze the almost sure exponential stability and exponential p-stability. The benchmark test model in numerical solutions, namely, one-dimensional linear scalar jump diffusion is examined first and easily verifiable conditions are presented. Then Markovian regime-switching jump diffusions are dealt with. Moreover, analysis on stability of numerical methods for linearizable and multi-dimensional jump diffusions is carried out. This is a joint work G. Yin and Haibo Li.

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MS24
Stock Trading Rules under a Switchable Market

This work provides an optimal trading rule that allows buying and selling of an asset sequentially over time. The asset price follows a regime switching model involving a geometric Brownian motion and a mean reversion model. The objective is to determine a sequence of trading times to maximize an overall return. The corresponding value functions are characterized by a set of quasi variational inequalities. Closed-form solutions are obtained.

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MS25
Toward Adaptive Control of the Systemic Inflammatory Response

Optimizing therapeutic treatment for the critically ill is a challenge that clinicians face due to the complexity of the inflammatory response. This talk will report on the use of state estimation methods and nonlinear model predictive control for finding optimal inputs for a reduced but highly nonlinear system of inflammation. We further discuss the progress and challenges toward implementing strategies to adapt this system to the patient system and improve predictability of the response.

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MS25

Multiple Model Predictive Control Approach to Personalized Anemia Management

This presentation introduces a new algorithm, based on the principles of Multiple Model Predictive Control (MMPC), for personalized dosing of Erythropoiesis Stimulating Agents (ESA) in hemodialysis patients. The algorithm learns patients dose-response profile from data in real time and generates new doses by combining outputs from individual MPCs. Results of the first human study show that this algorithm significantly improves stability of hemoglobin concentration over a standard population-based paper protocol approach.

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MS25

Model-Based Estimation and Control for Personalized Real-Time Glucose Control in Intensive Care

The benefits of targeted glucose control in post-surgical intensive care is a topic of debate, which we hypothesize is a result of increased hypoglycemia and interpatient variability. We synthesize: (i) a model-based receding horizon controller; (ii) an output regulator to eliminate hypoglycemia and penalize large insulin infusions; and (iii) an on-line moving horizon estimator to update the controller model to match individual patient dynamics as they evolve. The resulting system was tested using actual intensive care patient data.

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MS25

Characterization and Control of the Erk/MAPK Signaling Pathway in T Lymphocytes

The ability to characterize and selectively control signaling pathways within T cells will generate new approaches for therapeutic design and research tools in medicine and systems biology. We characterize the signaling pathways using model-based design of experiments and use the refined mathematical models to inform open-loop control of the Erk/MAPK intracellular signaling. This integrated approach was evaluated using experiments with Jurkat cells to track trajectories with short, moderate and extended durations of Erk phosphorylation.

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MS26

H_∞-Stability Analysis of Delay Systems of Neutral Type

The stability of linear neutral systems with commensurate delays has been largely studied in the literature. However, the critical case where neutral poles approach the imaginary axis has not been fully understood. In this work, we consider some classes of these systems, which furthermore have formal polynomials of multiple roots. First, the location of neutral poles with respect to the imaginary axis is determined through approximation of the poles. Then, H_∞-stability conditions are derived in the cases where all the poles of the system are in the left half-plane.

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MS26

Solution of An Infinite Dimensional Two-Point Boundary Value Problem Via the Principle of Least Action

A new approach for solving two point boundary value problems for conservative infinite dimensional systems is investigated. This new approach seeks to exploit the principle of least action in reformulating and solving such problems in the framework of optimal control. A specific and highly simplified problem involving a one dimensional wave equation is considered. The construction of a solution to the attendant optimal control problem is identified as crucial in applying this new approach.

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MS26

Root Locus of Infinite-Dimensional Systems

The root locus is an important tool for analysing the stability of linear finite-dimensional systems as a parameter is varied. However, many systems are modelled by partial differential equations or delay equations. A rigorous definition of the root locus appropriate for a wide class of systems is developed. As for finite-dimensional systems, any limit point of a branch of the root locus is a zero. However, the general asymptotic behaviour can be quite different. The theory will be illustrated with an delay equation.

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MS26

Numerical Computation and Implementation of H-Infinity Controllers for Infinite-Dimensional Systems

The mixed sensitivity minimization is considered for SISO infinite dimensional plants with low order weights. Previously it was shown that the optimal controller can be computed from singular values and vectors of a square matrix whose dimension is $\ell + n_1$, where ℓ is the number of unstable modes of the plant and n_1 is the degree of the sensitivity weight. This presentation shows that the dimension of the square matrix in question can be reduced n_1. Hence a connection of the skew Toeplitz approach with the Zhou-Khargonakar formulation can established. Examples from systems with time delays, as well as systems represented by partial differential equations, will be given and implementation issues are discussed.

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MS27

Tropicalizing the Simplex Algorithm

We present an analogue of the simplex algorithm, allowing one to solve tropical (max-plus) linear programming problems. This algorithm computes, using signed tropical Cramer determinants, a sequence of feasible solutions which coincides with the image by the valuation of the sequence produced by the classical simplex algorithm over the ordered field of Puiseux series. This is motivated in particular by deterministic mean payoff games (which are equivalent to tropical linear programming).

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MS27

A Max-plus Method for the Approximate Solution of Discrete-time Linear Regulator Problems with Non-quadratic Terminal Payoff

A new max-plus based method is developed for the approximate solution of discrete time linear regulator problems with non-quadratic terminal payoff. This new method is underpinned by the development of fundamental solutions to such discrete time linear regulator problems. In comparison with typical grid-based approaches, a substantial reduction in computational effort is observed in applying this new method. A number of simple examples are presented that illustrate this and other observations.

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MS27

Contraction of Riccati Flows Applied to the Convergence Analysis of a Max-Plus Curse of Dimensionality Free Method

The approximation error of McEneaney's curse-of-dimensionality free method for solving HJB equations was shown to be $O(1/(N\tau))+O(\sqrt{\tau})$ where τ is the time discretization size and N is the number of iterations. Here we use a recently established contraction result for the indefinite Riccati flow in Thompson's metric to show that under different technical assumptions, still covering an important class of problems, the error is only of $O(e^{-N\alpha\tau}) + O(\tau)$ where α is related to the convergence rate of the Riccati flow.

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MS28

Convex Lyapunov Functions and Duality for Convex Processes

Concepts of weak and strong asymptotic stability of convex processes, generalizing asymptotic controllability and detectability of linear systems in presence of constraints, are studied through convex Lyapunov functions. Duality between the two concepts is established, through convex conjugacy between a weak Lyapunov function for a convex process and Lyapunov function for the adjoint process.

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MS28

Numerical Computation of Nonsmooth Lyapunov Functions for Differential Inclusions

We present a method for the computation of piecewise linear Lyapunov functions for strongly asymptotically stable differential inclusions. The method relies on converting the usual Lyapunov function inequalities into the constraints of a linear optimization problem on the nodes of a grid covering a subset of the state space. Contrary to other numerical approaches, the resulting function does not only yield a numerical approximation to a Lyapunov function but indeed a (nonsmooth) real Lyapunov function.

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MS28

Robust Non-Zenoness of Piecewise Affine Systems with Applications to Complementarity Systems

In this talk, we discuss non-Zenoness, referred to as the existence of finitely many mode switchings on finite time, of a family of piecewise affine systems (PASs) subject to parameter and initial state uncertainties/perturbations. In particular, we show that there is a uniform bound on the number of mode switchings for a family of Lispchitz PASs, as along as their subsystem matrices are uniformly bounded. Its applications to linear complementarity systems will be discussed. Further, we present preliminary results for robust non-Zenoness of non-Lipschitz PASs, under the assumption of well-posedness.

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MS28

Control Problems for a Class of Set Valued Evolutions

The talk studies controllability problems for the reachable set of a differential inclusion. These were originally motivated by models of control of a flock of animals. Conditions are derived for the existence or nonexistence of a strategy which confines the reachable set within a given bounded region, at all sufficiently large times. Steering problems and the asymptotic shape of the reachable set are also investigated.

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MS29

Synchronization in Complex Oscillator Networks

This talk proposes an insightful approach to synchronization problems in complex networks based on algebraic graph theory. We present a novel synchronization condition applicable to a general coupled oscillator model. We rigorously establish that our condition is exact for various interesting network topologies and parameters. Via statistical studies we show that our condition predicts accurately the existence of stable synchronous solutions for generic networks as well as various power network test cases.

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MS29

Coordination and Synchronization of Weakly Coupled Harmonic Oscillators

We propose an approach for the analysis and design of weakly coupled harmonic oscillators for coordination and synchronization. Through a coordinate transformation and averaging, a sufficient condition is given for orbital stability of a targeted limit cycle, in terms of linear matrix inequalities on the coupling matrix. The condition guarantees orbital stability when the coupling is sufficiently weak. However, for design, the coupling can be strengthened for faster convergence through a line search to minimize the magnitude of the Floquet multiplier with the largest modulus. Our method allows for multiple oscillation patterns to be embedded as stable limit cycles into a single coupling matrix with a local distributed structure.

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MS29

Determining Steady-State Patterns and Their Stability in Lateral Inhibition Networks

We analyze spatial patterns on networks of cells where adjacent cells inhibit each other through contact signaling. The network is represented as an interconnection of identical individual dynamical systems. To predict steady state patterns we identify equitable partitions of the graph vertices, assigning them into disjoint classes. We use results from monotone systems theory to prove the existence of patterns with this structure. We study their stability properties and provide a small-gain type criterion.

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MS29

Weighted L2 Norm Contractions in Diffusively-Coupled Systems

We present conditions using contraction theory that guar-

antee synchrony in diffusively-coupled systems. The conditions we derive generalize and unify existing theory about asymptotic convergence of trajectories of reaction-diffusion partial differential equations as well as compartmental ordinary differential equations, and furthermore may be numerically verified using linear matrix inequalities. Our analysis also provides a useful perspective for studying spatial pattern formation arising from diffusion-driven instability. We discuss examples relevant to enzymatic cell signaling and coupled oscillators.

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MS30

A Nonlocal Free Boundary Problem and Financial Pricing for Retirement Benefits

We study a nonlocal parabolic variational inequality which is from the financial valuation of defined benefits retirement pension plan that allows early retirement. The paid benefits on retirement dependent on the salary at that time. The underlying salary is assumed to follow a jump-diffusion process. We characterize the financial value of the retirement benefits as the solution of an optimal stopping time problem, which corresponds to a variational inequality or a free boundary problem of an integro-differential operator of the parabolic type. The existence and uniqueness of the solution to the variational inequality are proved and the properties for related free boundary are discussed.

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MS30

A Law of the Iterated Logarithm for Sublinear Expectations

In this paper, with the notion of independent identically distributed (IID) random variables under sub-linear expectations initiated by Peng, we investigate a law of the iterated logarithm for capacities. It turns out that our theorem is a natural extension of the Kolmogorov and the Hartman-Wintner laws of the iterated logarithm.

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MS30

A Utility Model of Learning How to Consume Effectively

This paper proposes a utility model in which agents require effort to learn how to consume effectively. In this model, there is an ideal utility function of consumption that requires skill to achieve. At each time, there is a range of consumption levels for which the agent can consume at the full potential described by this ideal utility function, and consuming outside this range generates less than the potential utility. There is an optimal policy for expending effort to move the boundaries of the range of consumption levels at which the agent is skilled at consuming. When the range is narrow, the presence of this learning induces a kind of risk aversion in the large, and makes the indirect utility function more concave than it would otherwise be.

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MS30

Weak Necessary and Sufficient Stochastic Maximum Principle

In this paper we prove a weak necessary and sufficient maximum principle for Markov modulated stochastic optimal control problems. Instead of insisting on the maximality condition of the Hamiltonian, we show that 0 belongs to the sum of Clarke's generalized gradient of the Hamiltonian and Clarke's normal cone of the control constraint set at the optimal control. Under a joint concavity condition on the Hamiltonian and a convexity condition on the terminal objective function, the necessary condition becomes sufficient. We give examples to demonstrate the weak stochastic maximum principle.

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MS31

On Time-optimal Trajectories for a Car-like Robot with One Trailer

In addition to the theoretical value of challenging optimal control problmes, recent progress in autonomous vehicles mandates further research in optimal motion planning for wheeled vehicles. Since current numerical optimal control techniques suffer from either the curse of dimensionality, e.g. the Hamilton-Jacobi-Bellman equation, or the curse of complexity, e.g. pseudospectral optimal control and max-plus methods, analytical characterization of geodesics for wheeled vehicles becomes important not only from a theoretical point of view but also from a practical one. Such an analytical characterization provides a fast motion planning algorithm that can be used in robust feedback loops. In this work, we use the Pontryagin Maximum Principle to characterize extremal trajectories, i.e. candidate geodesics, for a car-like robot with one trailer. We use time as the

distance function. In spite of partial progress, this problem has remained open in the past two decades. Besides straight motion and turn with maximum allowed curvature, we identify planar elastica as the third piece of motion that occurs along our extremals. We give a detailed characterization of such curves, a special case of which, called *merging curve*, connects maximum curvature turns to straight line segments. The structure of extremals in our case is revealed through analytical integration of the system and adjoint equations.

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MS31

Sampling-Based Algorithms for Optimal Motion Planning

Sampling-based algorithms, such as the RRT and PRM, have revolutionized motion planning. In this talk, we analyze these algorithms in terms of convergence to optimal solutions, and we introduce two novel algorithms called the RRT* and the PRM* that guarantee asymptotic optimality, i.e., almost-sure convergence to optimal solutions. Moreover, we extend the application domain of sampling-based algorithms to a variety of other control problems, including differential games, stochastic optimal control, and planning with complex task specifications.

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MS31

Title Not Available

Abstract not available.

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MS31

Kinodynamic Rrt*: Asymptotically Optimal Motion Planning for Robots with Linear Dynamics

We present Kinodynamic RRT*, an incremental sampling-based approach for asymptotically optimal motion planning for robots with linear dynamics. Our approach extends RRT*, which was introduced for holonomic robots, by using a fixed-final-state-free-final-time controller that optimally connects any pair of states, where the cost function is expressed as a trade-off between the duration of a trajectory and the expended control effort. Our approach generalizes earlier work on RRT* for kinodynamic systems, as it guarantees asymptotic optimality for any system with controllable linear dynamics, in state spaces of any dimension. In addition, we show that for the rich subclass of systems with a nilpotent dynamics matrix, closed-form solutions for optimal trajectories can be derived, which keeps the computational overhead of our algorithm compared to traditional RRT* at a minimum.

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MS32

The Non Occurrence of the Lavrentiev Gap for Scalar Multidimensional Variational Problems

We consider an autonomous integral functional defined in the space of Sobolev functions on an open and bounded set, and that agree with a prescribed Lipschitz function on the boundary of the domain. Jointly with Pierre Bousquet and Giulia Treu we show, without assuming growth conditions, that the Lavrentiev gap does not occur for a wide class of Lagrangeans.

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MS32

Necessary and Sufficient Second-Order Optimality Conditions for Strong Solutions of Optimal Control Problems with Pure and Mixed Constraints

We provide optimality conditions for strong solutions of optimal control problems with pure and mixed constraints. Second-order necessary conditions are obtained by combining the sliding mode approach of Dmitruk and the conditions obtained by Bonnans and Hermant for weak solutions. Sufficient conditions and a characterization of the quadratric growth are obtained by extending the decomposition principle of Bonnans and Osmolovskiĭ.

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MS32

(Sup + Bolza)-Control Problems As Dynamic Differential Games

Minimum problems are considered where the payoff is the sum of a *sup* functional and a classical Bolza functional. Owing to the $\langle L^1, L^\infty \rangle$ duality, the (L^∞+Bolza)-control problem is rephrased in terms of a *static differential game*, where a new variable k plays the role of a *maximizer*. In this framework $1-k$ is regarded as the *available fuel* for the maximizer. The relevant (and unusual) fact is that this static game is equivalent to the corresponding *dynamic* differential game, which allows the (upper) value function to verify a rather simple boundary value problem.

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MS32

Approximate Maximum Principle for Systems with Nonsmooth Endpoint Constraints

In this talk we report necessary optimality conditions for finite-difference approximations of continuous-time control systems with nonsmooth endpoint constraints and cost function. These results justify stability of the Pontryagin Maximum Principle for continuous-time systems with partially nonsmooth data under discrete approximations.

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MS33

Time-Varying Input and State Delay Compensation for Uncertain Nonlinear Systems

A predictor-based controller is developed for nonlinear systems under time-varying (unknown) state and (known) input delays and additive disturbances. A desired trajectory-based predictor structure of previous control values facilitates the control design. A Lyapunov-Krasovskii functional analysis guarantees semi-global tracking when the delays are bounded and slowly varying. Numerical simulations illustrate improved performance over previous time-varying input delay control designs and robustness to combinations of simultaneous input and state delays.

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MS33

Numerical Implementation of Predictor Feedback for Nonlinear Plants with Input Delays

For nonlinear plants with large input delays, numerical approximation of the predictor mapping is the central problem for implementation of predictor-based feedback. We show that a numerical scheme for the predictor, in conjunction with a hybrid feedback that uses sampled measurements, achieves global stabilization of all forward complete nonlinear systems that are globally asymptotically stabilizable and locally exponentially stabilizable in the delay-free case. Special results are provided for the linear time invariant case.

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MS33

Stability and Distributed Control for Dynamic Networks with Time-Delays: Some New Results

Dynamic networks are pervasive across engineering and science. Their importance and complexity continues to challenge us to develop new stability criteria. Time delays are often unavoidable when there is information exchange across large-scale dynamic networks. Here we report on our recent work on small-gain methods to ensure stability for dynamic nonlinear networks with time-delays. Then, an application to distributed control for networks of nonlinear output-feedback systems with time delays is given.

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MS33

Robustness of Nonlinear Systems with Respect to Delay and Sampling of the Controls

Sampling and delays in nonlinear controllers present challenges that are beyond the scope of standard Lyapunov or small gain methods. Here we consider continuous time nonlinear time varying systems that are globally asymptotically stabilizable by state feedbacks. We study their closed loop stability under controls that are corrupted by delay and sampling. We establish robustness through a Lyapunov approach of a new type. We illustrate our work using the kinematics of a wheeled mobile robot.

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MS34

Semilinear Differential Inclusions with Non-Compact Evolution Operators: Solution Existence Results and Controllability

As it was pointed out by Triggiani in [R. Triggiani, A note on the lack of exact controllability for mild solutions in Banach spaces, SIAM J. Control Optim. 15 (1977), no. 3, 407-411], the exact controllability in finite time for linear control systems in infinite dimensional Banach spaces using locally L^p- controls, for $p > 1$, is in contradiction with the compactness of the associated C_0-semigroup. Thus, it is meaningful to introduce conditions assuring exact controllability for semilinear equations and not requiring the compactness of the semigroups or evolution operators generated by the linear part. In this talk two approaches are described. The first one is related with a regularity assumption on the non-linear term, formulated through a measure of non-compactness, see [V. Obukhovski, P. Zecca, Controllability for systems governed by semilinear differential inclusions in a Banach space with a non-compact semigroup, Nonlinear Anal. 70 (2009), no. 9, 3424-3436], [I. Benedetti, V. Obukhovskii, P. Zecca, Controllability for impulsive semilinear functional differential inclusions with a non-compact evolution operator, Discuss. Math. Differ. Incl. Control. Optim., 31 (2011), 39-69]. The other one exploits the weak topology of the state space, see [I. Benedetti, L. Malaguti, V. Taddei, Nonlocal semilinear evolution equations without strong compactness: theory and applications, BVP, 2013].

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MS34

Optimizing Spectral Parameters in Nonlinear Wave Equation Arising in High Intensity Ultrasound

Input your abstract, including TeX commands, here. We consider a third order in time equation which arises as a model of wave propagation in viscous thermally relaxing fluids. The nonlinear PDE model under consideration displays two important characteristics: (i) it is quasilinear and (i) it is degenerate in the principal part. The main goal of this talk is to present results on existence-nonexistence and decay rates for the solutions as a function of physical parameters in the equation.

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MS34

A New Numerical Method Based on Shape Calculus for State-Constrained Optimal Control Problems with Pdes

The talk is devoted to the analysis and the numerics of pointwisely state-constrained elliptic optimal control problem. The transfer of an idea from the field of ODE optimal control is the starting point. A geometrical splitting of the constraints is necessary to carry over this approach. This leads to an equivalent reformulation of the model problem as a new class of optimization problem: a hybrid of optimal control and shape-/topology optimization, a so–called set optimal control. This class is integrated into the abstract framework of optimization on vector bundles. By a comparison of the new optimality conditions with those known form literature it becomes apparent that the new approach involves higher regularity. Newton- and trial algorithms are presented and discussed in detail. The new method can be formulated in function space without any regularization. Some numerical tests illustrate its performance.

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MS34

Stabilization of Fluid Flows with Partial Information

We consider fluid flows governed by the Navier-Stokes equations and we are interested in the stabilization of a flow about an unstable stationary solution in the case of partial information. This means that we have some measurements and that we look for a control expressed in terms of an estimate of the velocity of the flow. In the case of a control acting in a Dirichlet boundary condition and when the observation is expressed in terms of the stress tensor or of the pressure at the boundary, the observation involves the derivative of the control at the boundary. This happens not only for the continuous system but also for discrete models obtained by finite element methods. This leads to unsual filltering and control problems. We shall present a new approach for determining a feedback control law and an estimator of finite dimension for the velocity of the flow. This work is in collaboration with J.-M. Buchot, M. Fournie', P. A. Nguyen, L. Hosseini, J. Weller.

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MS35

Lp Parameter Differentiability in Diffuse Optical Tomography

In this talk, an elliptic PDE coefficient inverse problem for image reconstruction in Diffuseff Optical Tomography (DOT) will be presented. We will motivate the need for regularization with sparsity constraints for the ill-posed inverse problem which requires L_p regularity with respect to the parameters. We will formulate a trilinear form to prove L_p differentiability of the forward operator in DOT.

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MS35

Solution of Ill-Posed Inverse Problems Through Local Variational Filtering

The method of local regularization has been shown to lead to fast numerical algorithms for inverse problems with special structure (e.g., Volterra problems) and the possibility for improved resolution of fine details of solutions. We present recent developments on the extension of this method to more general inverse problems through the solution of local variational problems with both quadratic and nonquadratic penalties (such as those associated with sparsity constraints).

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MS35

Discrete-Time Blind Deconvolution for Distributed Parameter Systems with Dirichlet Boundary Input and Unbounded Output with Application to a Transdermal Alcohol Biosensor

A scheme for the blind deconvolution of blood or breath alcohol concentration from biosensor measured transdermal alcohol concentration based on a parabolic PDE with Dirichlet boundary input and point-wise boundary output is developed. The estimation of the convolution filter corresponding to a particular patient and device is formulated as a nonlinear least squares fit to data. The deconvolution is then formulated as a regularized linear-quadratic programming problem. Numerical results involving patient data are presented.

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MS35

An Inverse Problem Involving Words

Abstract not available.

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MS36

A Decomposition Technique for Multi-agent Pursuit Evasion Games

We present a decomposition technique for a class of differential games and find a relation between the regularity of the solution and the possibility to decompose the problem. We have used this technique to solve a pursuit evasion game with multiple agents.

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MS36

Linear Programming and Averaging Approaches to Singularly Perturbed Optimal Control Problems

It is known that equating of the singular perturbations parameter to zero may not lead to "near optimality" in nonlinear singularly perturbed (SP) optimal control problems (OCPs) and that, if this is the case, then an appropriate way of dealing with such problems is an averaging approach. In this presentation, we will revisit some of the existing results and discuss new results on averaging of SP OCPs based on linear programming relaxations of the latter.

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MS36

Explicit Solutions for Singular Infinite Horizon Calculus of Variations

We consider a one dimensional infinite horizon calculus of variations problem (P), where the integrand is linear with respect to the velocity. The Euler-Lagrange equation, when defined, is not a differential equation as usual, but reduces to an algebraic (or transcendental) equation $C(x) = 0$. Thus this first order optimality condition is not informative for optimal solutions with initial condition x_0 such that $C(x_0) \neq 0$. To problem (P) we associate an auxiliary calculus of variations problem whose solutions connect as quickly as possible the initial conditions to some constant solutions. Then we deduce the optimality of these curves, called MRAPs (Most Rapid Approach Path), for (P). According to the optimality criterium we consider, we have to assume a classical transversality condition. We observe that (P) possesses the Turnpike property, the Turnpike set being given by the preceding particular constant solutions of the auxiliary problem.

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MS36

Results and Experiments of LMBFGS in High Dimensional nonlinear optimization on WORHP

Discretized optimal control problems typically lead to high dimensional nonlinear optimization. To solve these problems we need to determinate the Hessian matrix, which requires a lot of memory consumption. We present an ffiefficient algorithm for calculating the Hessian matrix, namely. the limited memory BFGS method (LMBFGS). Afterwards the results from the experiments on a software library for mathematical non- linear optimization WORHP are shown. Furthermore several examples from space applications are presented.

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MS36

Necessary and Sufficient Conditions for Turnpike Properties of Solutions of Discrete-Time Optimal Control Systems

We discuss necessary and sufficient conditions for turnpike properties of approximate solutions of nonautonomous discrete-time optimal control systems arising in economic dynamics which are determined by sequences of lower semicontinuous objective functions. To have these properties means that the approximate solutions of the problems are determined mainly by the objective functions, and are essentially independent of the choice of intervals and endpoint conditions, except in regions close to the endpoints.

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MS37

Causal Domain Restriction Techniques

For shortest path problems on graphs, the techniques to restrict the computational domain are well-known. We consider similar domain restriction techniques for continuous optimal trajectory problems. Unlike in the discrete case, this results in additional errors depending on grid size and the aggressiveness of restriction. We explore computational efficiency and accuracy of several such techniques. The resulting methods are particularly useful for higher-dimensional problems, for which refining the mesh in the entire domain is prohibitively costly.

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MS37

Simplicial A* Algorithm for Optimal Feedback Planning

The problem of robot navigation along the shortest path among obstacles on a n-dimensional smooth manifold is considered. An approximate shortest path is computed using the Simplicial Dijkstra Algorithm (SDA). Its heuristic-driven variation, called Simplicial A* Algorithm (SAA), avoids a costly omnidirectional wave-front propagation by using heuristics that "steer" the computation towards robot initial position but ensure optimality. Experiments show, however, that the SAA completes computations in roughly half the time that is required by the SDA. This performance improvement renders the SAA advantageous over the SDA for practical robotics applications.

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MS38

The Hamilton-Jacobi Bellman Approach for Solving State-Constrained Optimal Control Problems

Abstract not available.

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MS38

Sum-of-Squares Approach to Synthesis of Switching Guards in Hybrid Systems

We propose a numerically-based technique for synthesizing switching guards for hybrid systems to satisfy a given state-based safety constraint. In particular, we employ sum of squares (SOS) programming to design guards defined by semialgebraic sets that trigger mode switches, and we guarantee that the synthesized switching policy does not allow Zeno executions. We use an iterative algorithm to solve the resulting bilinear SOS program and we demonstrate our approach through several examples.

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MS38

Challenges in Computational Nonlinear Control Theory: An Overview

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MS38

Partial Observability for the Shallow Water Equations

We discuss a quantitative measure of partial observability for the shallow water equations. A first order approximation of an unobservability index using empirical gramian is discussed. For linear systems with full state observability, the empirical gramian is equivalent to the observability gramian. We present algorithms for computing partial observability using the nonlinear system and the linearized system given by the tangent linear model. This work has applications to optimal sensor placement for numerical weather prediction.

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MS39

Extensions of Chronological Calculus and Chow-Rashevskii Theorem in Infinite Dimensions

We present an extension of the Chronological Calculus, originally developed by Agrachev and Gamkrelidze, which is valid for the study of control systems on infinite-dimensional C^k-smooth manifolds with C^k-smooth dynamics and controls which are merely measurable in time. Using techniques of nonsmooth analysis on smooth manifolds, we derive a generalization of the Chow-Rashevski theorem for control problems on infinite-dimensional manifolds modeled over smooth Banach spaces.

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MS39

Distributed Continuous-Time Dynamics for Linear Programming

We consider a general linear programming problem with equality and inequality constraints whose information structure is distributed across a multi-agent system. We develop a distributed algorithmic solution where, in contrast to existing methods, each agent converges to its local component of a global minimizer. Our solution is scalable with the problem dimension and is based on saddle-point methods for augmented Lagrangians. The stability analysis uses nonsmooth analysis, Lyapunov techniques, and set-valued analysis for dynamical systems.

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MS39

Hybrid Control Systems and Variational Analysis

Tools from variational analysis are employed to design control laws for the stabilization of hybrid dynamical systems. Key regularity properties of the set-valued mappings emerging from Lyapunov inequalities permitting the construction of state-feedback laws are determined. In particular, conditions guaranteeing the existence of stabilizing controllers given by continuous functions of the state and by functions with minimum norm are presented. Examples illustrate the conditions and controller constructions.

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MS39

Variational Analysis and Stochastic Hybrid Systems

We use results from variational analysis to propose a modeling framework for a class of stochastic hybrid systems. Randomness appears only in the jump map of the hybrid dynamics. Systems with non-unique solutions are handled in the framework. Connections are made to a recently-developed modeling approach for non-stochastic hybrid systems that also relies heavily on concepts from variational analysis. Time permitting, stability concepts will be described and sufficient Lyapunov conditions provided for stability.

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MS40

Existence of the Value Function for Controlled Two-Dimensional Lévy Processes

The main purpose of this work is to establish the existence, and study the regularity, of a solution to a Hamilton-Jacobi-Bellman (HJB) equation arising in the minimization of an infinite horizon singular stochastic control problem, where the state process is a controlled two-dimensional Lévy process. In our model the controlled process is allowed to be a general two-dimensional Lévy process, in particular to have jumps. This makes that the HJB equation has an integral term coming from the jumps of the controlled process, and which is naturally related to the integral term of its infinitesimal generator. This is a joint with D. Hernandez and V. Rivero.

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MS40

On HJB Equation for a Finite Time Optimal Consumption Problem

We consider a finite time optimal consumption problem where an investor wants to maximize the expected HARA utility of consumption and terminal wealth. We treat a stochastic factor model that the means returns and the volatilities of the risky assets depend on the underlying economic factors formulated as the solutions of stochastic differential equations. Using dynamic programming approach we can derive the Hamilton-Jacobi-Bellman (HJB) equation. We show the existence of a solution for HJB equation. The uniqueness of the solution with certain growth condition will be also proved.

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MS40

Shadow Prices and Well Posedness in the Problem of Optimal Investment and Consumption with Transaction Costs

We revisit the optimal investment and consumption model of Davis and Norman (1990) and Shreve and Soner (1994), following a shadow-price approach similar to that of Kallsen and Muhle-Karbe (2010). Making use of the completeness of the model without transaction costs, we reformulate and reduce the Hamilton-Jacobi-Bellman equation for this singular stochastic control problem to a non-standard free-boundary problem for a first-order ODE with an integral constraint. Having shown that the free boundary problem has a smooth solution, we use it to construct the solution of the original optimal investment/consumption problem in a self-contained manner and without any recourse to the dynamic programming principle. Furthermore, we provide an explicit characterization of model parameters for which the value function is finite.

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MS40

The Valuation of Banxico Put Option

Banco de Mexico (Banxico) issues a novel instrument to buy US dollars. They allow to implement Monetary Policy and control reserve levels. They give the right to sell dollars back to Banxico with strike price indexed to the FIX. The option can be exercised ONLY if the current FIX is below its own last 20-day moving average. We will discuss the arbitrage free price of Banxico's put option through a new stopping problem with constraints.

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MS41

Online Computation of Backwards-Reachable Sets for Robust Linear Discrete-Time MPC

We propose a method of computing feasible sets of states and inputs for linear robust MPC based on locally exploring parametric solutions of a sequence of linear programming problems. The approach avoids the computationally demanding problem of determining entire backwards reachable subsets of state space. Instead we use active constraints of the feasibility problem to construct constraints for a family of robust MPC solvers via an online algorithm with complexity that scales linearly with horizon length.

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MS41

Separable Prediction Structures in Model Predictive Control Under Uncertainty

The talk discusses the notion of separable prediction structure, which formalizes the deployment of separable state and control action predictions and allows for a theoretically sound and computationally efficient synthesis of model predictive control (MPC) under uncertainty. The proposed paradigm outperforms the existing robust MPC approaches in the linear-polytopic case. Furthermore, it is shown that the framework can be extended, with a relative ease, to the settings of linear time-varying and nonlinear systems under uncertainty.

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MS41

On the Inherent Robustness of Suboptimal Model Predictive Control

We address the *inherent robustness* properties of nonlinear systems controlled by suboptimal model predictive control, i.e., when a *suboptimal* solution of the (generally nonconvex) optimization problem, rather than an element of *the optimal* solution set, is used for the control. We extend existing results by relaxing the continuity conditions of the feasible set, and we establish inherent robustness of an example featuring both a discontinuous feedback control law and a discontinuous optimal MPC cost function.

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MS41

Stability Robustness in Stochastic Model Predictive Control That Generates Discontinuous Feedbacks

We consider robustness of stochastic stability for discrete-time stochastic systems under discontinuous control laws, including MPC. For controlled deterministic, discrete-time systems the existence of a continuous Lyapunov function for the closed-loop system establishes nominal robustness of asymptotic stability, even with discontinuous control law. Under basic regularity assumptions, we show that for discrete-time stochastic systems under discontinuous control laws, asymptotic stability in probability is robust to sufficiently small strictly causal perturbations.

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MS42

Pseudospectral Computational Optimal Control for Multiscale Systems

In aerospace control applications, systems with multiple time scales are frequently encountered. Since standard pseudospectral methods apply the same discretization grid on all state trajectories and controls, it reduces computational efficiency in dealing with dynamical systems with multiple time scales. We will present some recent developments in pseudospectral computational optima control algorithms, which allow states with different time scales to de discretized on different grids. Simulation results on space applications will also be presented.

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MS42

Experimental Implementation of Pseudospectral Motion Planning

Pseudospectral (PS) motion planning is a version of PS optimal control theory developed for solving navigation problems in robotics. In this talk, we discuss the mathematics of the PS motion planning algorithm and the experimental implementation of the approach on an autonomous ground robot. Recent work aimed at developing a small form factor embedded system for deploying the PS motion planning algorithm as part of an on board navigation system will also be discussed.

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MS42

Iterative Svd Algorithm for Optimal Ensemble Control Synthesis

Designing optimal controls for manipulating an ensemble of bilinear systems is imperative for wide-ranging applications in quantum control and robotics. We develop an iterative optimization-free algorithm for synthesizing optimal ensemble controls for bilinear systems based on the singular value decomposition. At each step, the bilinear ensemble system is approximated by a time-varying linear ensemble system. The convergence of the algorithm is illustrated theoretically and through examples of pulse design in quantum control.

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MS42

Stochastic Optimal Control of Nonholonomic Vehicles

While stochastic processes are useful models for wind disturbances influencing the dynamics of small unmanned aerial vehicles, in our work we also use them to model possible vehicles paths. Based on this, we compute target tracking controllers, decentralized multi-vehicle formation control and resolve the spatio-temporal conflict of vehicle trajectories. This talk reviews several years of research in my group and is illustrated by examples, including unmanned aerial vehicles, airport traffic and scaled-down robot experiments.

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MS43

Sparse Controls in State-Constrained Elliptic Optimal Control Problems

This talk deals with pointwise state-constrained optimal control problems governed by semilinear elliptic equations. We look for optimal controls that are sparse. To this end, the L^1-norm of the control is added to the cost functional. From the first order optimality conditions we deduce the sparsity of the optimal control as well as some new regularity results for the Lagrange multiplier associated to the state constraints. Second order conditions and stability properties are also analyzed.

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MS43

Sparse Controls for the Optimization of Traveling Wave Fronts

We consider optimal sparse control problems for reaction diffusion equations, like the Schlögl equation in spatial dimension one and two as well as the FitzHugh-Nagumo system in spatial dimension two. Both have in common, that their solutions form pattern of travelling wave fronts or even spiral waves. We derive first-order necessary optimality conditions for the associated control problems as well as sparsity of the controls and present various numerical examples.

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MS43

Sparse Optimal Controls for the Linear Wave Equation

Optimal control problems for the linear wave equation are investigated with $L^2(I, \mathcal{M}(\otimes))$ for the space of controls. Here $\mathcal{M}(\otimes)$ denotes the space of regular Borel-measures. Its Fenchel-dual problem involves a smooth cost and bilateral box-constraints, which are amenable for numerical realisation. On the basis of the KKT-conditions sparsity properties of the optimal controls can be derived. The numerical discretization is based on mixed finite elements in space and a Petrov-Galerkin method in time. The controls are discretized by Dirac-measures in space. The resulting optimization problems are solved by a semi-smooth Newton method

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MS43

A Priori Error Analysis for Discretization of Sparse Elliptic Optimal Control Problems in Measure Space

In this talk we consider an optimal control problem, where the control variable lies in a measure space and the state variable fulfills an elliptic equation. This formulation leads to a sparse structure of the optimal control. For this problem we prove a new regularity result for the optimal solution and derive a priori error estimates for a finite element discretization, which significantly improve the estimates known from the literature. Numerical examples for problems in two and three space dimensions illustrate our results.

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MS44

Efficient Tracking and Pursuit of Moving Targets by Heuristic Solution of the Traveling Salesman Problem

We consider a problem in which a large number of moving targets must be intercepted by a single agent as quickly as possible. Decision-making about which target to pursue next is driven by the repeated heuristic solution of the traveling salesman problem (TSP), which is compared to a greedy algorithm over different problem parameterizations. The proposed method is superior when the targets move at low speeds, and its relative performance improves as sensor noise worsens.

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MS44

Stochastic and Dynamic Vehicle Routing Problems in Robotics and Transportation Systems

This paper surveys recent results in dynamic vehicle routing (DVR) problems, aiming at the on-line planning of routes to perform tasks that are generated over time by an exogenous stochastic process. We consider a variety of scenarios relevant for applications in robotics and transportation networks, based on different models for tasks and/or vehicles. In each DVR scenario, we adopt a rigorous technical approach that relies upon methods from queueing theory, combinatorial optimization, and stochastic geometry.

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MS44

Autonomous Data Collection in Underwater Sensor Networks

This talk considers two problems related to path planning for Autonomous Underwater Vehicles (AUVs): (1) data gathering from an underwater sensor network equipped with acoustic modems and (2) autonomous inspection of the submerged portion of a ship hull. I will present path planning methods that extend variants of the TSP to these domains, and I will show how nonparametric uncertainty modeling can be used to optimize the efficiency of mobile data collection.

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MS44

Procrustes Based Approximations to the Traveling Salesman Problem

We present a novel heuristic approach for computing the solution of the traveling salesman problem (TSP). We relax the TSP to the Procrustes problem and compute the resulting optimal solution. We then construct a homotopy between the solution of the Procrustes problem and the distance matrix to improve the original solution. The solution of the homotopy is then used to bias the Lin-Kernighan approach. We find that this approach provides significant improvement over the standard approach of using minimum spanning trees. In particular, for randomly generated TSPs, our approach is found to find lower cost solutions in 85% of the problems. For TSPLIB challenge problems, we find lower cost solutions in nearly all tested examples.

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MS45

A Priori Error Estimates for Parabolic Optimal Control Problems with Pointwise Controls

We consider a parabolic optimal control problem with a pointwise control in space, but variable in time, in two space dimensions. W use the standard continuous piecewise linear approximation in space and the first order discontinuous Galerkin method in time to approximate the problem numerically. Despite low regularity of the state equation, we show almost optimal $h^2 + k$ convergence rate for the control in L^2 norm. The main ingredients of the analysis are the new global and local error estimates in $L^2([0, T]; L^\infty(\Omega))$ norms.

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MS45

On a Class of Semi-Infinite Optimization Problems Arising in Pde-Constrained Optimal Control

Many practical applications of PDE-constrained optimization are influenced by finitely many, possibly time-dependent, control parameters rather than by control functions that can vary arbitrarily in space. Oftentimes, pointwise state constraints are also part of a problem formulation. The associated active sets then typically admit a certain structure that can be used in the numerical analysis of such problems. In the recent past, Merino, Tröltzsch, Vexler, and the speaker have worked on convergence results for the finite element discretization of problems with finite-dimensional control space and obtained higher rates than for control functions. In this talk, we present some related theoretical results as well as some numerical experiments.

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MS45

Optimal Control Methods for the Schlögl Model

Optimal control problems for a class of semilinear parabolic equations with cubic nonlinearity are considered. This class is also known as the Schlögl model. Main emphasis is laid on controlling traveling wave fronts as typical solutions to the state equation. We discuss the analysis of the problem and report on the application of nonlinear conjugate gradient methods to a variety of numerical test examples. Moreover, the performance of model reduction by POD is studied.

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MS45

Adjoint Consistent Gradient Computation with the Damped Crank-Nicolson Method

The talk is concerned with a damped version of the Crank-Nicolson (CN) Method for the solution of parabolic partial differential equations. As it is well known, the CN-Methods needs to be damped in order to cope with irregular initial data, due to the missing smoothing property. Since the adjoint of the CN-Method is again a CN-Method, shifted by half a timestep, it is not surprising that a similar problem occurs for the adjoint time stepping scheme. In this talk, we will derive an adjoint consistent damped CN-Scheme that ensures sufficient damping of the dual problem. The necessity of these modifications will be discussed along the use of the dual-weighted residual (DWR) method for the adaptive solution of the Black-Scholes equation. The consequences for optimization problems with parabolic PDEs will be discussed.

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MS46

Cooperative Control for Flocking of Mobile Agents Using L1 Adaptive Architecture

This talk discusses an adaptive cooperative control framework for a system of multiple mobile agents with nonlinear dynamics. The adaptive cooperative control framework is an extension of L1 adaptive control architecture to multi-agent systems, which consists of three components: state predictors for extended dynamics of agents, adaptive laws, and decentralized control laws. The state predictors provide the estimation of each agents extended dynamics which includes its own local dynamics and interacted dynamics with other agents. The adaptive laws can make the estimated states from state predictors arbitrarily close to the real states by reducing the time step of integration. Each control law is a combination of a velocity consensus term, a gradient-based term on an artificial potential function, and an uncertainties canceling term. Rather than reproducing the flocking motion, this cooperative control framework provides a general decentralized coordination method for achieving velocity consensus and regulation of relative distances among nonlinear dynamical agents. 2-D flocking simulation with nonlinear dynamics is provided to demonstrate the presented adaptive cooperative control algorithm.

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MS46

$\mathcal{L}_\infty$ Adaptive Control of High Speed Personal Watercraft

Reliable and effective use of high-speed watercraft for unmanned operations relies on advanced control systems capable to govern it across its entire operational spectrum. The complex nonlinear time-varying dynamics of the watercraft can be partly identified through full scale sea trials, which calls for robust controllers able to manage large system's uncertainties. The $\mathcal{L}_\infty$ adaptive control enforces the desired maneuvering and positioning features into the watercraft, providing uniform performances despite of operational and environmental conditions.

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MS46

Regulation of Anesthesia Delivery via L1-Adaptive Control

In this paper, we present an application of L1-adaptive control design to anesthesia delivery during surgery. Our main objectives are the design of feedback controllers ensuring that the patient's Bispectral Index profile tracks a prespecified reference trajectory, and demonstrating robustness to inter-patient variability. For the design of the controllers we developed patient models based on clinical trial data. Controller switching mechanisms and specific safety measures are considered in the paper. Simulation results are provided demonstrating the effectiveness of the control methods.

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MS46

L1Simplex for Co-Stability in Computer-Controlled Systems

As the complexity of systems increases, it becomes very challenging to ensure system reliability in the presence of failures. To address this issue, we propose L1Simplex architecture, which contains the safety monitor, the high-performance-controller (HPC), the L1-adaptation-based high-assurance-controller (HAC), and the control switching logic. When failures are detected by the safety monitor, the controller will be switched from the HPC to the HAC. We show that L1Simplex can efficiently handle both software and physical failures.

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MS47

The Principle of Least Action and Solution of Two-Point Boundary Value Problems on a Limited Time Horizon

A conservative system follows a trajectory according to the principle of least action. The dynamics may be posed as an optimal control problem. Solution of this allows one to convert two-point boundary-value problems into initial value problems through idempotent convolution with the fundamental solution. We consider the n-body problem. Representing the gravitational potential as a maximum of quadratic forms, one obtains a differential game. The fundamental solution is a set of Riccati solutions.

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MS47

Informational Issues in Deterministic Dynamic Games

In deterministic dynamic games the relevant information patterns are either open-loop control or state feedback control. In games where the players use open-loop control the optimal controls are obtained using the necessary conditions of optimal control and in games where the players have perfect information and state feedback action is used the solution is obtained using the method of dynamic programming. In this talk deterministic two person dynamic games are considered where one player is constrained to use open-loop control whereas his opponent uses feedback action we shall refer to mixed games. The solution of mixed games requires an adaptation of the method of dynamic programming. The difficulties associated with the solution of mixed games are discussed and the solution of mixed linear-quadratic games is derived.

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MS47

Max-Plus Methods for Optimal Attitude Estimation on So(3)

In this work we introduce the use of recently developed min/max-plus techniques in order to solve the optimal attitude estimation problem in filtering for nonlinear systems on the special orthogonal (SO(3)) group. This work helps obtain computationally efficient methods for the synthesis of deterministic filters for nonlinear systems - i.e., optimal filters which estimate the state using a related optimal control problem. The technique indicated herein is validated using a set of optimal attitude estimation example problems on SO(3).

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MS47

Stochastic Games, Nonexpansive Operators and O-Minimal Structures

We show that the normalized iterates of a non-expansive operator converge (as the number of iterations tends to infinity) as soon as this operator is definable in some o-minimal structure. This implies convergence of the values, as the horizon tends to infinity, for some classes of zero-sum stochastic games with finitely many states and definable payoffs and transitions . We also give some applications to risk sensitive control and non-linear Perron-Frobenius theory.

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MS48

The Hamiltonian Cycle Problem and Markov Decision Processes

Abstract not available.

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MS48

Stochastic Differential Games Against Nature: An Application to Optimal Control with Unknown Parameters

In this talk we will describe a problem regarding the optimal control of Markov diffusion processes with unknown parameters. Our approach is to rewrite the problem as a game against nature, where player 1 is the controller and player 2 selects, from a given set, the values of the unknown parameter. Hence, an optimal policy for the original problem will be equivalent to a min-max equilibrium associated to the game. Our analysis is based on the dynamic programming technique.

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MS48

Stochastic Games Against Nature: Applications to Finance

We develop a pure game-theoretic approach to option pricing in a multi-dimensional market (rainbow options), where risk-neutral probabilities emerge automatically from the robust control evaluation. The process of investment is considered as a zero-sum game of an investor with the Nature. The talk will be based mostly on my paper http://arxiv.org/abs/1105.3053 (to appear in "Risk and Decision Analysis') and my Chapter 4 of the joint monograph P. Bernhard et al "The Interval Market Model in Mathematical Finance: Game-Theoretic Methods.' Birkhäuser, 2012, p. 217-290.

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MS48

Average Optimal Strategies for Zero-Sum Markov Games with Poorly Known Payoff Function on One Side

We are concerned with two-person zero-sum Markov games with Borel spaces under a long-run average criterion. The payoff function is possibly unbounded and depends on a parameter which is unknown to one of the players. The parameter and the payoff function can be estimated by implementing statistical methods. Thus, our main objective is to combine such estimation procedure with a variant of the so-called vanishing discount approach to construct an average optimal pair of strategies for the game. Our results are applied to a class of zero-sum semi-Markov games.

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MS49

Quickest Detection and Sequential Classification in Systems with Correlated Noise

We address the problems of sequential classification and quickest detection in Brownian channels with correlated noise. In the former we demonstrate that the maximum of two SPRTs is asymptotically optimal in identifying the channel with signal as the error probabilities decrease to zero, while in the latter, asymptotic optimality of the minimum of two CUSUM stopping rules in detecting the first instance of a signal as the frequency of false alarms decreases to zero.

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MS49

A Mean Field Stochastic Growth Model and Its Out-of-Equilibrium Behavior

This work introduces a framework of mean field consumption-accumulation optimization, where the production dynamics are generalized from stochastic growth theory by addressing the negative mean field effect on efficiency. The HARA utility is adopted by the agents. We construct decentralized strategies by the Nash certainty equivalence approach. We further investigate the out-of-equilibrium behavior of the mean field dynamics and identify interesting nonlinear phenomena, including stable equilibria, limit cycles and chaos.

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MS49

Apply Stochastic Optimal Control to Investment and Consumption Problems with Regime-Switching

This presentation is concerned with optimal investment and consumption problems in continuous-time Markov regime-switching models. An investor distributes his/her wealth between a risky asset (a stock) and a risk-less asset (a bond) and consumes at a non-negative rate from the bond account. The market parameters (the interest rate, the appreciation rate and the volatility rate of the stock) are assumed to depend on a continuous-time Markov chain with finite number of states (the regimes). The objective of the optimization problem is to maximize the expected total utility of consumption. Due to regime-switching, the Hamilton-Jacobi-Bellman (HJB) equation for this optimal control problem is given by a system of coupled nonlinear partial differential equations. We apply the stochastic optimal control methods to study the value functions and the optimal control policies. These results extend that for the cases without regime-switching.

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MS49

A Measure Approach to Impulse Control Problems

Only finitely many actions will occur in any bounded interval of time for control problems in which each action incurs a positive cost. Typically these problems are formulated so that the decision-maker selects sequences of stopping times $\tau := \{\tau_k : k \in \mathbf{N}\}$ and jump amounts $Y := \{Y_k : k \in \mathbf{N}\}$ such that at time τ_k the state process X instantaneously jumps from $X(\tau_k-)$ to $X(\tau_k-)+Y_k$. The paired sequeneces (τ, Y) form an impulse control policy. A criterion is then used to compare the efficacy of the policies. This talk establishes a general formulation of impulse control problems for state processes characterized as solutions to martingale problems for their generators. It shows how to reformulate a discounted control problem in terms of expected occupation measures, resulting in an imbedding in an infinite-dimensional linear program. Specific examples are considered in which the analysis of auxiliary linear programs having fewer constraints determines the optimal value and identifies an optimal impulse control policy.

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PP1

Modeling and Analysis of Adaptive-Conversion-Ratio-Based Bidirectional Switched-Capacitor Converter

This research deals with the modeling and analysis of a new adaptive-conversion-ratio-based bidirectional switched-capacitor converter (BSCC) for the bidirectional step-up/down DC-DC conversion and regulation. The power part consists of one mc-stage cell and one nc-stage cell in cascade between low-voltage (LV) and high-voltage (HV) sides to obtain a step-up gain of (mc x nc) from LV to HV sides, or a step-down gain of 1/(mc x nc) from HV to LV at most. Here, the adaptive-conversion-ratio (ACR) control with adapting stage number m,n is suggested to change the topological path for a proper step-up/down gain: (m x n) or 1/(m x n) (m=1,2,...,mc, n=1,2,...,nc) so as to improve efficiency, especially for the lower desired voltage. Finally, the performance of this converter is verified experimentally on a BSCC prototype, and all results are illustrated to show the efficacy of this scheme.

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PP1

Nonlinear Model Reduction and Control

In many physical systems, real time or near real time controllers must be computed using a reduced order model. Furthermore, parameter dependent systems introduce another layer of complexity to the selection and development of the reduced order model. In this presentation, we demonstrate both the online and offline computation cost of several controllers each based on a different parametric model reduction technique. Finally, the performance of each is measured in a high fidelity simulation.

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PP1

Pseudo-Real Time Monitoring and Control of Abnormal Occurrences of Fire Incidents with the Mining of the National Fire Data System (NFDS)

Fire prevention/control is a global issue for sustainability. Every outbreak of fire is analyzed and recorded into NFDS (or similar systems in other countries) on a daily basis. Through data-mining, we develop a prediction model considering the context related to fire occurrences and an effective monitoring system for proactive alarm generations, based on control charts. Multi-scale monitoring selecting appropriate space and time is adapted to reduce false alarms. Multivariate context-sensitive monitoring is investigated with adjusting control limits on-line, based on the predicted moving bandwidth of fire incidents.

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PP1

Tip Position Estimation and Control of a Flexible Cantilever with Kalman Estimator Using An Accelerometer

Tip position control of a flexible cantilever is difficult due to the non-minimum phase dynamics that result from the finite propagating speed of a mechanical wave along the cantilever. In this research, tip position estimation and control using a light and cheap accelerometer that does not bring any significant change to the dynamics of the cantilever is studied. A Kalman estimator is designed with the flexible cantilever model to estimate tip position based on tip acceleration information. The estimated tip position is used to a fuzzy logic controller to verify reliability. Also, the performance of the estimator with the accelerometer is presented and discussed.

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PP1

Phase Transition and Optimization of Granular Flow Down a Chute with Successive Turning Points

Granular materials are ubiquitous in industrial, mining and pharmaceutical processes. This paper studies the phase transition and optimization of granular flow down a chute with successive turning points with experiments and discrete element simulations. The dependence of flux on channel width show dilute to dense flow trantision. A remarkable bistable state appears near the transition point, depending on the original condition. Base on this discovery, one can optimize the flow rate along such channels.

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PP1

Markowitz's Mean-Variance Asset-Liability Management With Regime Switching: A Time-Consistent Approach

In this work, we consider the mean-variance asset-liability management problem under a continuous time Markov regime switching model. This regime switching feature is good in capturing the bull-bear market feature but notorious in yielding a time-inconsistent optimal solution. This time-inconsistent feature means that the dynamic programming identity is no longer valid and so are its subsequence derivations in finding the optimal solution. By using an extended Hamilton-Jacobi-Bellman equation, we can successfully solve the problem via finding the equilibrium value function and equilibrium feedback control. This equilibrium control will be time-consistent in the sense that it is also an equilibrium control for any subproblems. We have also shown that the equilibrium value function is quadratic in liability and affine in surplus; and the equilibrium control is affine in liability. This is a joint work with J. Q. Wei, K. C. Wong and S. C. P. Yam.

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PP1

Cauchy Integral Formula to Compute the Exponential of a Matrix

In this paper we derive a kind of formula for computing the ex- ponential of a matrix by symbolic computation. This formula can exactly express each element of the desired exponential function of a matrix as a Cauchy integral of some known functions. A numerical solution can be given by computing the value of the Cauchy integral by numerical computation.

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