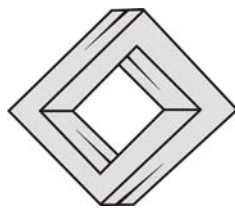


First North American Meeting on  
Industrial and Applied Mathematics  
NAMIAM 2010

Huatulco, Oaxaca, México  
December 7-10, 2010  
Universidad del Mar



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# Committees, Coordinators and Sponsors

## 1 Committees

### Steering Committee

#### SMM

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**Victor Pereyra**, Weidlinger Associates, victor@wai.com

## **Scientific Committee**

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### **SIAM**

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## **Local Organizing Committee**

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**José Antonio Muñoz Gómez**, UdeG, jantoniomex@gmail.com

**Edgar Possani** ITAM

### **UMAR**

**Abel R. Vargas López**

**Yolanda Olvera**

**Martín Zuñiga**

## 2 Coordinators

### Applied Probability and Statistics

**SMM:** Mogens Bladt, IIMAS-UNAM

**CAIMS:** David McDonald, Université d'Ottawa

**SIAM:** Erkki Somersalo, Case Western University

### Numerical Analysis and Linear Algebra

**SMM:** Humberto Madrid, UAdeC

**CAIMS:** Chen Greif, University of British Columbia  
Bob Russell, Simon Fraser University

**SIAM:** Daniel Szyld, Temple University

### Optimization and Operations Research

**SMM:** Roger Z. Ríos, UANL

**CAIMS:** Patrice Marcotte, Université d'Montréal

**SIAM:** Joanna Papakonstantinou, Rice University

### Biomathematics

**SMM:** Jorge Velasco, IMP

**CAIMS:** Michael Mackey, McGill University

**SIAM:** Carlos Castillo-Chávez, Arizona State University

### Oil, Weather and Geo-science Modeling

**SMM:** Susana Gómez, IIMAS-UNAM

Miguel A. Moreles, CIMAT

**CAIMS:** Nicholas Kevalahan, McMaster University

**SIAM:** Alison Malcolm, MIT

### Computational Fluid Dynamics

**SMM:** Eduardo Ramos, CIE-UNAM

**CAIMS:** Eliot Fried, McGill University

**SIAM:** Héctor D. Ceniceros, University of California Santa Barbara

## Financial Mathematics and Economy

**SMM:** Beatriz Rumbos, ITAM

**CAIMS:** Tom Salisbury, York University

**SIAM:** Kay Giesecke, Stanford University

## Inverse Problems and Control

**SMM:** Jacobo Oliveros, BUAP

**CAIMS:** Uri Ascher, University of British Columbia

Huaxiong Huang, York University

**SIAM:** Matthias Heinkenschloss, Rice University

## General Session

**SMM:** Lucero de Teresa, IMATE-UNAM

Patricia Saavedra, UAM-I

**CAIMS:** Uri Ascher, University of British Columbia

Bob Russell, Simon Fraser University

**SIAM:** Daniel Szyld, Temple University

## Poster Session

**SMM:** Joaquín Delgado, UAM-I

María Luisa Sandoval, UAM-I

**CAIMS:** Fahima Nekka, Université d'Montréal

**SIAM:** Leticia Velázquez, University of Texas El Paso



### 3 Sponsors

<p>Sociedad Matemática Mexicana (SMM) Canadian Applied and Industrial Mathematics Society (CAIMS) Société Canadienne de Mathématiques Appliquées et Industrielles (SCMAI) Society for Industrial and Applied Mathematics (SIAM) Consejo Nacional de Ciencia y Tecnología (CONACYT) Red de Modelos Matemáticos y Computacionales (RMMC) Centre de Recherches Mathématiques (CRM) Fields Institute Pacific Institute for the Mathematical Sciences (PIMS) MITACS Universidad del Mar (UMAR)</p>
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# Chapter 1

## Schedules

Plenary Talks, pág. 25				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		2	4	6
10:00-10:55				
11:00-11:25		Poster Session and Coffee Break		
11:30-12:55				
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50	Registration	3	5	7
18:00-18:55	1			
19:00-19:25	Opening Ceremony			
19:30-20:00				Closing Ceremony

**1. Separable Nonlinear Least Squares: From Ancient History to Today**

*Victor Pereyra*

**2. Coating flows on rotating cylinders**

*Mary Pugh*

**3. Modeling, Estimation and Control of Dynamical Systems**

*Onesimo Hernández-Lerma*

**4. A least-squares/finite element method for the numerical solution of the Navier-Stokes-Cahn-Hilliard system modeling a contact line motion**

*Roland Glowinski*

**5. Solving PDE constrained optimization problems with multiple right hand sides**

*Eldad Haber*

**6. How useful is Mathematical Economics**

*Gilberto Calvillo*

**7. Inverse Problems and Cloaking**

*Gunther Uhlmann*

Computational Fluid Dynamics, Room 5 <small>pág. 29</small>				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25		1.1	1.9	
10:30-10:55		1.2	1.10	
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55		1.3	1.11	
12:00-12:25		1.4		
12:30-12:55		1.5		
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk	1.6		
18:30-18:55		1.7		
19:00-19:25	Opening Ceremony	1.8		
19:30-20:00				Closing Ceremony

**1.1 The Immersed Boundary Method with Finite Element Elasticity**

*Boyce Griffith*

**1.2 Quasibidimensional Model for the Dynamics of Air Bubbles in a Hele-Shaw Cell**

*Eduardo Ramos*

**1.3 To Be Announced**

*Eliot Fried*

**1.4 A Multigrid Method for the Coupled Implicit Immersed Boundary Equations**

*Robert D. Guy*

**1.5 Optimal Acceleration of High-Order Conservative Semi-Lagrangian Schemes in Graphics Cards Using CUDA**

*Julian T. Becerra-Sagredo,*

**1.6 Modelling and Simulation of Sap Flow and Heat Transport in Trees**

*John Stockie*

**1.7 A Non-Stiff Boundary Integral Method for 3D Porous Media Flow with Surface Tension**

*Michael Siegel*

**1.8 Two and Three-Phase Flow in Porous Media: Mathematical, Numerical and Computational Models**

*Luis Miguel De la Cruz Salas*

**1.9 Applying Spectral Methods to Investigate the Instability of Shear Flows**

*Francis Poulin*

**1.10 Boundary integral simulations of separated flows and interfacial Stokes flows**

*Monika Nitsche*

**1.11 Fixed Grid Methods for Problems with (Moving) Interfaces**

*Huaxiong Huang*

Optimization and Operations Research, Room 2 pág. 35				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25		2.1	2.9	
10:30-10:55		2.2	2.10	
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55		2.3	2.11	
12:00-12:25		2.4	2.12	
12:30-12:55		2.5	2.13	
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk	2.6		
18:30-18:55		2.7		
19:00-19:25	Opening Ceremony	2.8		
19:30-20:00				Closing Ceremony

**2.1 Convex Reformulations**  
*Yasmín A. Ríos Solís*

**2.6 Network Pricing under Elastic Demand**  
*Gilles Savard*

**2.2 On the Nullstellensatz Method for Combinatorial Optimization**  
*Susan Margulies*

**2.7 A Consensus Model for Group Decision Support Based on Valued Outranking Relations**  
*Juan Carlos Leyva López*

**2.3 New Results Concerning the Price of Anarchy**  
*Patrice Marcotte*

**2.8 Alleviating the Impact of an Epidemic**  
*Cecilia Zenteno*

**2.4 Designing Routes for WEEE Collection: The Vehicle Routing Problem With Split Loads and Date Windows**  
*José Luis González Velarde*

**2.9 On a conjecture of C. Sundberg: A nonlinear programming based investigation**  
*Roland Glowinski*

**2.5 MultiObjective Non-Linear Model Predictive Control of Chemical Reactors**  
*Antonio Flores*

**2.10 A Mathematical Programming Approach to Pollution Trading**  
*Vicente Rico Ramírez*

**2.11 Applied Optimization and Operations Research at the Centre for Operations Excellence (Sauder School of Business at UBC)**

*Maurice Queyranne*

**2.12 Efficient Territory Design Planning by a Novel Location-Allocation-Improvement**

**Algorithm**

*Roger Z. Rios Mercado*

**2.13 Optimality of the Neighbor Joining Algorithm and Faces of the Balanced Minimum Evolution Polytope**

*Ruriko Yoshida*



Inverse Problems and Control, Room 3 pág. 43				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25		3.1	3.9	
10:30-10:55		3.2	3.10	
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55		3.3	3.11	
12:00-12:25		3.4	3.12	
12:30-12:55		3.5		
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk	3.6		
18:30-18:55		3.7		
19:00-19:25	Opening Ceremony	3.8		
19:30-20:00				Closing Ceremony

**3.1 Chaotic Gradient Descent Methods**  
*Kees van den Doel*

**3.2 On an Inverse Problem for the Nonlinear Wave Equation**  
*Marcos A. Capistrán*

**3.3 Stochastic Collocation for Optimization Problems Governed by Stochastic Partial Differential Equations**  
*Drew Kouri*

**3.4 Optimal Control Problems in Insurance and Finance**  
*Huaxiong Huang*

**3.5 Identification of a Pressure Dependent Heat Transfer Coefficient**  
*A. Fraguera*

**3.6 A Stochastic Newton Method for Large-Scale Statistical Inverse Problems**  
*Omar Ghattas*

**3.7 Level Set Regularization for Highly Ill-Posed Distributed Parameter Estimation Problems**  
*Uri Ascher*

**3.8 Automatic Correction of the Personal Orientation in Space**  
*V.V. Alexandrov*

**3.9 Model Reduction for Decision Under Uncertainty**  
*Karen Willcox*

- |                                                                                                                   |                                                         |
|-------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| 3.10 Numerical Methods for Seismic Inversion                                                                      | <i>Alexandre Grebennikov</i>                            |
| <i>Michael P. Lamoureux</i>                                                                                       | 3.12 Aerodynamic Shape Optimization Under Uncertainties |
| 3.11 Solution of Direct and Coefficient Inverse Problems for Partial Differential Equations by General Ray Method | <i>Volker Schulz</i>                                    |

Applied Probability and Statistics, Room 4 pág. 52				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25		4.1		
10:30-10:55		4.2		
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55		4.3		
12:00-12:25				
12:30-12:55				
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk	4.4		
18:30-18:55		4.5		
19:00-19:25	Opening Ceremony	4.6		
19:30-20:00				Closing Ceremony

**4.1 Geometric Stick-Breaking Processes for Continuous-Time Nonparametric Modeling**  
*Ramsés H. Mena*

**4.2 Performance of WiFi Protocols**  
*David McDonald*

**4.3 Some Counting Processes to Study Ozone Air Pollution**  
*Eliane R. Rodrigues*

**4.4 Spatio-Temporal Model for Lightning Caused Forest Fire Ignitions, using Shot-**

**noise Cox Point Processes**  
*Carlos Díaz Avalos*

**4.5 The Expected Gerber-Shiu Penalty Function for Classical Risk Processes Perturbed by  $\alpha$ -Stable Processes**  
*Ekaterina Todorova Kolkovska*

**4.6 Phase-Type Distributions and Heavy Tails**  
*Mogens Bladt*

Numerical Analysis and Lineal Algebra, Room 1 <small>pág. 55</small>				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25				5.7
10:30-10:55				5.8
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55			5.1	5.9
12:00-12:25			5.2	5.10
12:30-12:55			5.3	5.11
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk		5.4	5.12
18:30-18:55			5.5	5.13
19:00-19:25	Opening Ceremony		5.6	5.14
19:30-20:00				Closing Ceremony

**5.1 Numerical Solution of a Nonlinear Matrix Equation Arising in Nano Research**

*Chun-Hua Guo*

**5.2 A Multi-level Full Approximation Scheme in Space and Time**

*Michael Minion*

**5.3 New Functional for Improving the Distribution of the Area of the Cells in Plane Structured Grids**

*Pablo Barrera-Sanchez*

**5.4 New Rigorous Perturbation Bounds for Cholesky, LU and QR Factorizations**

*Xiao-Wen Chang*

**5.5 Krylov Subspace Recycling with an Application to Acoustics**

*Eric De Sturler*

**5.6 Some Results in Solving Partial Differential Equations on Irregular Spatial Domains Using Finite Differences Schemes and Logically Rectangular Grids**

*Jose-Gerardo Tinoco-Ruiz*

**5.7 Orbit Continuation for Computing Stable/Unstable Manifolds**

*Eusebius Doedel*

**5.8 Stability of GMRES Convergence and Approximate Preconditioning**

*Mark Embree*

**5.9 Clusters in the Helbing's Improved Model**

*Patricia Saavedra*

- 5.10 **An Analysis of Low-Rank Modifications of Preconditioners for Saddle Point Systems**  
*Chen Greif*
- 5.11 **Algebraic Optimizable Schwarz Methods for the Solution of Banded Linear Systems and PDEs on Irregular Domains**  
*Daniel B. Szyld*
- 5.12 **Computation of Matrix Functions using the Hadamard Product**  
*Luis Verde-Star*
- 5.13 **A Simple Technique for Solving Partial Differential Equations on Surfaces**  
*Steve Ruuth*
- 5.14 **Edge Detection by Normalized Cut and Power Method, and an Application to Motion Detection**  
*Humberto Madrid*

Oil, Weather and Geo-science Modeling, Room 2 <small>pág. 62</small>				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25				6.3
10:30-10:55				6.4
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55				6.5
12:00-12:25				6.6
12:30-12:55				6.7
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk		6.1	6.8
18:30-18:55			6.2	6.9
19:00-19:25	Opening Ceremony			6.10
19:30-20:00				Closing Ceremony

**6.1 Adaptive Wavelet Discretization of PDEs on the Sphere: a Framework for Geophysical Flow**  
*Nicholas Kevlahan*

**6.2 3D Parallel Elastodynamic Modeling of the Wave Propagation of Earthquakes: Supercomputer Implementation and Urban and Industrial Applications**  
*M. Chavez*

**6.3 Dispersion from Flares in a Cross-Wind**  
*Bruce R. Sutherland*

**6.4 Development of High Performance Numerical Schemes and Tools for High-End Earth Science Applications**  
*Tony Drummond*

**6.5 On Modeling Subdiffusion and the**

**problem of deconvolution in well test analysis**  
*Miguel Ángel Moreles*

**6.6 Numerical PDE Solvers for Exploration Seismology**  
*Michael P. Lamoureux*

**6.7 The General Curvilinear Environmental Model**  
*Jose Castillo*

**6.8 Characterization of Fractured Oil Reservoirs with Global Optimization**  
*Susana Gómez*

**6.9 The Three-Dimensionalization of Barotropic Instability**  
*Francis Poulin*

**6.10 Sensitivity Analysis in Climate. The  
Ensemble Bred Vector**

*Juan M. Restrepo*

Biomathematics, Room 3 pág. 69				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25				7.5
10:30-10:55				7.6
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55				7.7
12:00-12:25				
12:30-12:55			7.1	
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk		7.2	7.8
18:30-18:55			7.3	7.9
19:00-19:25	Opening Ceremony		7.4	7.10
19:30-20:00				Closing Ceremony

**7.1 Multiple Waves for the Same Pandemic: Local Transportation and Social Distancing Explain the Dynamics of the A-H1N1 Epidemic During 2009 in México**  
*Marco Arieli Herrera-Valdez*

**7.2 Stochastic Modeling of HIV Infection in Treated Patients**  
*Daniel Coombs*

**7.3 Mechanisms of Resistance in Populations Dynamics**  
*Brenda Tapia Santos*

**7.4 A Model of Thyroid Cancer Initiation and Growth in Autoimmune Thyroiditis**  
*Stephen J. Merrill*

**7.5 Quantitative Analysis of Single Particle Tracking Experiments: Applying Ecological**

**Methods in Cell Biology**  
*Gerda De Vries*

**7.6 Interaction Between Meandering Spiral Waves and Circular Shape Obstacles: a Numerical Study**  
*Daniel Olmos Liceaga*

**7.7 Animal Gaits and Symmetries of Periodic Solutions**  
*Martin Golubitsky*

**7.8 Numerical Solution of the Chemical Master Equation: mRNA Bursting in a Gene Network with Negative Feedback Regulation**  
*Moisés Santillán*



**7.9 Objective Dosing Regimens Based on  
an Integrative PK/PD Formalism**

*Fahima Nekka*

**Mode Development in Optimal Biological  
Branching Processes: the Patterning Pro-  
gram in Lung Formation**

*Pablo Padilla*

**7.10 Growth Rate and Shape as Possible  
Control Mechanisms for the Selection of**

Financial Mathematics and Economy, Room 4 pág. 74				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25			8.1	8.9
10:30-10:55			8.2	8.10
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55			8.3	
12:00-12:25			8.4	
12:30-12:55			8.5	
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk		8.6	8.11
18:30-18:55			8.7	8.12
19:00-19:25	Opening Ceremony		8.8	8.13
19:30-20:00				Closing Ceremony

**8.1 The Exchange of Derivatives. An Analysis with a Functional of Cumulative Prospect Theory**  
*Erick Treviño-Aguilar*

**8.2 Credit Risk in the Private World**  
*Luis Seco*

**8.3 Optimal Investment With Performance Fees**  
*Gerard Brunick*

**8.4 Calibration of Vasicek and CIR Models Via a Generating Function Approach**  
*Marianito R. Rodrigo*

**8.5 A Novel Approximation To Loss Probabilities Of Credit Portfolios**  
*Meng Han*

**8.6 A Cournot-Stackelberg Model of Supply Contracts With Financial Hedging**  
*Martin B. Haugh*

**8.7 An LP Model to Settle Transactions in the Mexican Securities Market**  
*Alejandro De los Santos*

**8.8 On the Pensioner's Management Problem: a Time Consistent Approach**  
*Oumar Mbodji*

**8.9 Crisis! Investment and Consumption in Market Models with Stochastic Volatility, Jumps and Contagion**  
*Tom Hurd*

**8.10 Portfolio Turnpike in Incomplete Markets**  
*Hao Xing*

**8.11 Optimal Utilization of Variable Annuity Guarantees**

*Thomas S. Salisbury*

**8.12 Unified Multi-Name Credit-Equity Modeling: a Multivariate Time Change Approach**

*Rafael Mendoza-Arriaga*

**8.13 On Pricing and Hedging Problems of Relevance to Liquid Reinsurance Markets and Insurance Securities**

*Diego Hernández Rangel*

General Session - 1, Room 6 pág. 82				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25		9.1	9.9	9.17
10:30-10:55		9.2	9.10	9.18
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55		9.3	9.11	9.19
12:00-12:25		9.4	9.12	9.20
12:30-12:55		9.5	9.13	9.21
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk	9.6	9.14	9.22
18:30-18:55		9.7	9.15	9.23
19:00-19:25	Opening Ceremony	9.8	9.16	9.24
19:30-20:00				Closing Ceremony

**9.1 Extensional Flow of a Viscoelastic Thread**

*David O. Olagunju*

**9.2 Fluid Flow and Tracer Transport Simulation in Oil Reservoirs using a Direct Streamline Approach**

*Manuel Coronado*

**9.3 Regulatory Networks, Chemical Oscillations, Biological Switches, and Intrinsic Noise in Cells.**

**Why and What for?**

*Eduardo S. Zeron*

**9.4 Smooth Global Solutions to the Eikonal Equation**

*Jaime Cruz-Sampedro*

**9.5 Application of the Method of Kali-**

**nay and Percus to Find Effective Diffusion Coefficients for Biological Channels**

*Inti Pineda*

**9.6 Estimation of Patient Compliance Based on Limited Sampling Information**

*Olivier Barrière*

**9.7 A Mixed Finite Element Method with Exactly Divergence-Free Velocities for Incompressible Magnetohydrodynamics**

*Xiaoxi Wei*

**9.8 Enfoque Numérico Al Problema De Identificación De Dominio En Un Problema De Valor En La Frontera Con Condición Dirichlet**

*Alejandro Torres*

- |                                                                                                                                                                                          |                                                                                                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>9.9 "5a Fachada", A System for Optimizing, Designing and Constructing Roofs With Light Russ-Based Steel to Conserve Energy and Materials</b><br/> <i>Luz Angélica Caudillo</i></p> | <p><i>A.V. Balueva</i></p> <p><b>9.18 Patchy Solutions of Hamilton Jacobi Bellman Partial Differential Equations</b><br/> <i>Arthur J. Krener</i></p>                              |
| <p><b>9.10 Policies for Replacement of Water Meters in Mexico City Using Renewal Theory</b><br/> <i>Jorge Armando Castro Hernández</i></p>                                               | <p><b>9.19 On Reconstruction of Temperature-Dependent Parameters in Multiphysics Phenomena</b><br/> <i>V. Bukshtynov</i></p>                                                       |
| <p><b>9.11 Representation and Modeling Uncertainties In Fuzzy and Expert Systems</b><br/> <i>Ildar Batyrshin</i></p>                                                                     | <p><b>9.20 Computational Modeling of Temperature Profiles of a Combustion Tube with Temperature Dependent Thermal Conductivity</b><br/> <i>J. Hernandez-Perez</i></p>              |
| <p><b>9.12 Selecting Against Antibiotic-Resistant Pathogens: a Control-Theoretic Approach</b><br/> <i>Rafael Peña Miller</i></p>                                                         | <p><b>9.21 Efficient Calculation of Frequencies of Extended Molecular System with the Mobile Block Hessian Method</b><br/> <i>An Ghysels</i></p>                                   |
| <p><b>9.13 Chaos and MMOs in Singularly Perturbed Circuits with a Cubic Nonlinearity</b><br/> <i>Wiesław Marszałek</i></p>                                                               | <p><b>9.22 Computational Modeling of a Micro-Mixer: an Application of Navier-Stokes and Diffusion Equations</b><br/> <i>Ciro F. Flores Rivera</i></p>                              |
| <p><b>9.14 Modeling the Adaptive Immune Response in HBV Infection</b><br/> <i>Abdessamad Tridane</i></p>                                                                                 | <p><b>9.23 Robust Optimization for Robot Positioning by Using a Hybrid Optimizer: Estimation of Distribution Algorithm and Dogleg</b><br/> <i>Eusebio Eduardo Hernández M.</i></p> |
| <p><b>9.16 Neonatal Seizure Detection using Blind Adaptive Fusion</b><br/> <i>Aleksandar Jeremic</i></p>                                                                                 | <p><b>9.24 Multiobjective Optimization using Estimation of Distribution Algorithms Based on The Empirical Selection Distribution</b><br/> <i>S. Ivvan Valdez</i></p>               |
| <p><b>9.17 Modeling of Hydrogen Embrittlement Cracking in Pipe-Lines Under Big Pressures</b></p>                                                                                         |                                                                                                                                                                                    |

General Session - 2, Room 7 pág. 99				
Time	Tuesday	Wednesday	Thursday	Friday
9:00-9:50		Plenary Talk	Plenary Talk	Plenary Talk
10:00-10:25		10.1	10.5	
10:30-10:55		10.2	10.6	10.8
11:00-11:25		Poster Session and Coffee Break		
11:30-11:55		10.3	10.7	10.9
12:00-12:25		10.4		10.10
12:30-12:55				10.11
13:00-16:00		Lunch		
16:00-16:50	Registration	RMMC	MITACS	Round Table Discussion
17:00-17:50		Plenary Talk	Plenary Talk	Plenary Talk
18:00-18:25	Plenary Talk			10.12
18:30-18:55				10.13
19:00-19:25	Opening Ceremony			10.14
19:30-20:00				Closing Ceremony

**10.1 An Agent-Based Model With Drift and Cross-Immunity for Influenza**

*Jorge A. Alfaro-Murillo*

**10.2 Seismic Wave Propagation in Fractured Media: a Discontinuous Galerkin Approach**

*Jonás D. De Basabe*

**10.3 Hodge Decomposition and Maxwell's Equations**

*Jintao Cui*

**10.4 The Role of Symmetric and Asymmetric Division of Cancer Cells in Developing Drug Resistance**

*Cristian Tomasetti*

**10.5 Computational Modeling of ESWT**

*Kirsten Fagnan*

**10.6 Optimization and Adaptive Fitting of Mixed-Effects Models with Correlated Random-Effects**

*Guangxiang Zhang*

**10.7 BAK-Pack: Solve Sparse Linear Systems with Krylov Subspace Methods**

*Héctor Alonso Hernández*

**10.8 Risk-Sensitive Second and Third Degree Optimal Filtering Design and Applications**

*MA. Aracelia Alcorta G.*

**10.9 Comparison of Different Solution Strategies for Structure Deformation using Very Fine Discretization**

*Jose Miguel Vargas*

**10.10 Estimation of Lane-Change Parameters for a Traffic Flow Model in a Multi-Lane Street**

*Héctor Flores-Cantú*

**10.11 New Models for the Piece-Mold-Machine Manufacturing Planning**

*M. A. Saucedo-Espinosa*

**10.12 The Hidden Energy in Irreversible Fluctuations as the Origin of Noise In-**

**duced Phenomena: Stochastic Focusing**

*Lisa Bishop*

**10.13 Elliptic Super Regularization for Non-linear Inverse and Ill-Posed Problems**

*Akhtar Khan*

**10.14 A Classification of Infinite Dimensional Walrasian Economies and the Economic Crisis**

*Elvio Accinelli*

**Poster Session, Lobby, University Auditorium** pág. 110

Time	Wednesday	Thursday	Friday
11:00-11:25	11.1	11.14	11.27
	11.2	11.15	11.28
	11.3	11.16	11.29
	11.4	11.17	11.30
	11.5	11.18	11.31
	11.6	11.19	11.32
	11.7	11.20	11.33
	11.8	11.21	11.34
	11.9	11.22	11.35
	11.10	11.23	11.36
	11.11	11.24	11.37
	11.12	11.25	11.38
	11.13	11.26	

**11.1 New Models for the Piece-Mold-Machine Manufacturing Planning**
*Mario Alberto Saucedo Espinosa*
**11.2 Numerical Solution of the Poisson-Nernst-Planck on Fuel Cells**
*Miguel González Vázquez*
**11.3 Avances Sobre el Problema Inverso de la Tomografía de Capacitancia Eléctrica**
*Félix Augusto Aquino Camacho*
**11.4 Control System of Vertical Posture Dynamic Simulator**
*M. Reyes Romero*
**11.5 Lower Bound for Robustness in a Quasi Random Rumor Spreading Scheme**
*Charles Drake Poole*
**11.6 Identificación y Aproximación de Fuentes Bioeléctricas en el Cerebro Considerando una Geometría Simple de la**
**Cabeza**
*José Julio Conde Mones*
**11.7 El Fenómeno de Gibbs y el Método de Filtrado de  $\sigma$  - Factor de Lanczos**
*J. Miguel Uribe*
**11.8 A Stable Algorithm for Recovering Bioelectrical Sources Represented by Dipoles**
*María Monserrat Morín Castillo*
**11.9 Diseño de un Control Óptimo Discreto para un Robot Móvil**
*Gelacio Salas Ortega*
**11.10 Composition of Physical Quantities that Fulfill Group Properties**
*E. García Martínez*
**11.11 Natural Convection in a Square Cavity with Participating Medium**
*Manuel A. Ramírez*



- |                                                                                                                                                                                   |                                                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11.12 Numerical Simulations of Two Dimensional Bubbles<br><i>Saúl Piedra</i>                                                                                                      | 11.23 El Primer Teorema Fundamental de Valuación de Activos<br><i>Alejandro Sánchez Peralta</i>                                                               |
| 11.13 Two models for the simulation of pedestrian traffic<br><i>Jorge Daniel González Aróstico</i>                                                                                | 11.24 Recycling data for efficient numerical interpolation-based model order reduction<br><i>Aarón De La Concha G.</i>                                        |
| 11.14 On the pensioner's management problem: A time consistent approach<br><i>Oumar Mbodji</i>                                                                                    | 11.25 Segmentation and face detection<br><i>Jessica T. Rojas Cuevas</i>                                                                                       |
| 11.15 Non Hermitian Operators and Quantum Finance<br><i>Oswaldo González-Gaxiola</i>                                                                                              | 11.26 Optimal control theory in vaccination<br><i>Sunmi Lee</i>                                                                                               |
| 11.16 High Performance Computing Applied to Numerical Solution of Coupled Problems<br><i>Roberto Carlos Medel Morales</i>                                                         | 11.27 Proyecto de cortabilidad de pieles en Italmoda<br><i>Ricardo Romo Romero</i>                                                                            |
| 11.17 To Be Announced<br><i>F. Benítez</i>                                                                                                                                        | 11.28 Modeling metabolic cooperation in a public goods game<br><i>Ayari Fuentes-Hernández</i>                                                                 |
| 11.18 Mathematical Properties of Wavelet Filters Used in Ultrasound and Mammography Images for Different Applications<br><i>C. Juárez-Landin</i>                                  | 11.29 Medición y administración de riesgo operacional con redes Bayesianas<br><i>Francisco Martinez</i>                                                       |
| 11.19 Validación Numérica y Experimental de un Algoritmo de Identificación de Fuentes Bioeléctricas de Tipo Polar<br><i>B. Minerva Rodríguez Ramírez</i>                          | 11.30 Solution of the Heat Equation with the Method of Multiple Scales<br><i>Francisco Javier Bautista Zúñiga</i>                                             |
| 11.20 Diseño de Leyes de Control por Retroalimentación de Salida para la Alineación de la Antena de un Satélite con la Antena de la Estación en Tierra<br><i>Rafael Cruz José</i> | 11.31 A Model to Show That The Maximum Earthquake Size Increases With Increasing Convergence Rate and Decreasing Lithospheric Age<br><i>A. Muñoz Diosdado</i> |
| 11.21 Application to Inverse Problems for Partial Differential Equations<br><i>D. Assaely León Velasco</i>                                                                        | 11.32 A Method for Segmentation of Ultrasound Images with Intensity Inhomogeneity Correction<br><i>Miguel Angel Lopez</i>                                     |
| 11.22 Diseño de un Mini Sistema de Aeronavegación Basado en Sensores de Tecnología MEMS y GPS<br><i>J. F. Guerrero-Castellanos</i>                                                | 11.33 An Elementary Characterization of Low Order Matrix Exponential Distributions<br><i>Margarita Tetlalmatzi-Montiel</i>                                    |

**11.34 Persistence, Extinction and Invasion of an Epimedic in a Population**

*Luis O. Barbosa*

**didácticos y de investigación**

*J. Guerrero Castellanos*

**11.35 Parameters estimation for a SIR epidemiological model with spatial adaptation to the metropolitan zone of Guadalajara**

*Luis Zarate-Siordia*

**11.37 To Be Announced**

*Sadati Seyedmahalleh*

**11.38 On the Asymptotic Properties of the ARX Models in Adaptive Tracking**

*V. Vazquez Guevara*

**11.36 Modelado, diseño e implementación de un mini vehículo aéreo pvtol con fines**

## Chapter 2

# Abstracts

### Plenary Talks

#### 1. Separable Nonlinear Least Squares: From Ancient History to Today

**Victor Pereyra**

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Separable nonlinear least squares (SNLS) were identified in the early 1970's by G. H. Golub, H. Scolnick, I. Guttman and myself. A method called Variable Projections (VP) was developed, a detailed implementation was described and an actual computer program was written and widely distributed.

There was a flurry of activity on the theoretical and implementation aspects during the first 10 years that helped influence the application of VP to a variety of areas. A successful one showed up from the beginning: exponential data fitting and modeling, because of its prevalence in many areas and because the available methods had difficulties, specially in situations where noise was present.

The appearance of the WWW made it easier to check the impact of these techniques in later years and to our surprise we saw constant activity and new applications appearing until this day. That led to a 2003 review article by Golub and myself and more recently to a book "Exponential Data Fitting and its Applications" by G. Scherer and myself as Editors, where leading researchers present a wide variety of applications where the use of SNLS has made a difference.

I will provide an overview of the topic area from its inception to today, put the whole area in perspective, particularly with regard to applications, and suggest new venues for continued research and application.

## **2. Coating flows on rotating cylinders**

**Mary Pugh**

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This talk is intended for a broad audience. We consider a horizontal cylinder, rotating slowly about its center. A viscous fluid is on the outside of the cylinder, coating the cylinder as it rotates. We consider a lubrication approximation of the Navier-Stokes equations for the regime in which the fluid film is relatively thin and the surface tension is relatively large. The resulting lubrication model may have no steady state, a unique steady state, or more than one steady state. Using both numerics and analysis, we consider the dynamics of this flow, including whether or not solutions can become singular in finite time. This is joint work with Marina Chugunova (Toronto) and Roman Taranets (Nottingham).

## **3. Modeling, Estimation and Control of Dynamical Systems**

**Onesimo Hernández-Lerma**

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This is a presentation of some recent topics on the modeling, estimation, and control of deterministic and stochastic dynamical systems. These topics include adaptive control, control of partially observable systems, and minimax control, and they are illustrated with examples from engineering, economics, and other areas.

## **4. A least-squares/finite element method for the numerical solution of the Navier-Stokes-Cahn-Hilliard system modeling a contact line motion**

**Roland Glowinski**

Department of Mathematics  
University of Houston, Houston, TEX USA  
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In this lecture, we will discuss the numerical solution of the Navier-Stokes-Cahn-Hilliard system modeling the motion of the contact line separating two immiscible incompressible fluids near a solid wall. The method we employ combines a finite element space approximation with a time discretization by operator-splitting. To solve the Cahn-Hilliard part of the problem, we use a least-squares/conjugate gradient method. Our approach is validated by the results of numerical experiments

## **5. Solving PDE constrained optimization problems with multiple right hand sides**

**Eldad Haber**

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Many parameter estimation problems involve with a parameter-dependant PDEs with multiple right hand sides. The computational cost and memory requirements of such problems increases linearly with the number of right hand sides. For many applications this is the main bottleneck of the computation. In this work we show that problems with multiple right hand sides can be reformulated as stochastic optimization problems that are much cheaper to solve. We discuss the solution methodology and use two model problems to show the effectiveness of our approach.

## **6. How useful is Mathematical Economics**

**Gilberto Calvillo**

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The development of humankind has been fostered by Science and Technology since ancient times. In turn, Mathematics has played an important role in such a process. In fact, Science, Technology and Mathematics grew together feeding back each other through the solution of real problems.

Social Scientists have tried to use the same concepts and tools of Natural Sciences several times. They have also developed some mathematical tools originated in their own fields. There is, however, disagreement about the success of mathematization of the Social Sciences. This issue is becoming crucial for several reasons that I will try to outline in the talk.

Today, the Human race is confronted with problems so big and complex that we, humans, need to developed and/or deployed tools that are able to cope not only with natural phenomena, but with social processes. In the talk I will present some of these problems and dig very superficially in the mathematical tools that are available for one of the social sciences: Economics.

## **7. Inverse Problems and Cloaking**

**Gunther Uhlmann**

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gunther@math.washington.edu

We describe recent theoretical and experimental progress on making objects invisible to detection by electromagnetic waves, acoustic waves and quantum waves. Maxwell's equations have transformation laws that allow for design of electromagnetic materials that steer light around a hidden region, returning it to its original

path on the far side. Not only would observers be unaware of the contents of the hidden region, they would not even be aware that something was being hidden. The object, which would have no shadow, is said to be cloaked. We recount some of the history of the subject and discuss some of the mathematical issues involved.

## **1 Minisymposia-Computational Fluid Dynamics**

### **1.1 The Immersed Boundary Method with Finite Element Elasticity**

**Boyce Griffith**

Leon H. Charney Division of Cardiology  
New York University School of Medicine  
boyce.griffith@nyumc.org

The immersed boundary (IB) method is a general framework for problems of fluid-structure interaction in which an elastic structure is immersed in a viscous incompressible fluid. The IB approach to such problems is to use a Lagrangian description of the immersed structure and an Eulerian description of the viscous incompressible fluid. In the spatially continuous setting, coupling between Lagrangian and Eulerian descriptions is mediated by integral transforms with Dirac delta function kernels. When the continuous equations are discretized for computer simulation, these delta function kernels are replaced by regularized versions of the delta function. In this talk, I will describe a novel version of the IB method that uses a finite element (FE) description of the immersed elastic structure. Unlike the conventional IB method, our IB-FE approach permits the discretization of the elastic structure to be significantly coarser than that of the fluid in which it is immersed without introducing leaks at fluid-structure interfaces. This capability is facilitated by the Lagrangian-Eulerian coupling schemes employed by the IB-FE method, schemes that are generalizations of the Lagrangian-Eulerian interaction equations used in standard IB methods. Applications of both the conventional IB method and also the IB-FE method to problems of cardiac fluid dynamics will be presented.

### **1.2 Quasibidimensional model for the dynamics of air bubbles in a Hele-Shaw cell**

**Saúl Piedra y Eduardo Ramos**

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The dynamics of air bubbles ascending in a water filled Hele-Shaw cell is studied by numerically solving the mass and momentum conservation equations for the two interacting fluids. The conservation equations are coupled at the water-fluid interface whose position is obtained with a front tracking technique. The bubble position and shape, and the flow inside and outside the bubble are described. The shape of the bubble is determined by the motion of the water surrounding the bubble, and the surface tension. The terminal velocity is a function of the density difference and the geometry of the bubble. The effect of the walls of the Hele-Shaw cell is accounted for in the model by including a brake term proportional to the corresponding component of the bubble centroid velocity in the momentum conservation equation. The proportionality constant is a free parameter. It is found

that the bubbles follow a zigzag trajectory as they ascend. The bubbles acquire elliptic shapes that oscillate  $\pm 45^\circ$  around their geometrical center, with the largest inclination angle at the turning points of the zigzag motion. Also, the bubbles take a larger eccentricity at the same positions. The Reynolds number of the bubbles is 372 and vortex shedding is observed. All dynamical properties are in quantitative agreement with experimental results.

### 1.3 To Be Announced

Eliot Fried

### 1.4 A Multigrid Method for the Coupled Implicit Immersed Boundary Equations

Robert D. Guy, Bobby Philip<sup>1</sup>

Department of Mathematics

University of California Davis

<sup>1</sup>Oak Ridge National Laboratory

In this talk a multigrid method for solving the linearized immersed boundary equations that arise in implicit time discretizations is presented. The method simultaneously solves the equations on the Eulerian and Lagrangian grids. Numerical tests that compare the efficiency of the method with an explicit-time method are presented for a variety of test problems, including different geometries, variable numbers of Lagrangian points, and different constitutive laws. Analytical results are presented for simplified model problems to provide insight into the success and limitations of the method. Solving the implicit equations is only slightly more computationally expensive than solving the explicit equations, and time dependent simulations are up to 100 times more efficient. By using the multigrid method as a preconditioner for a Krylov method, the robustness of the method is extended and the efficiency of the computations is even greater for very stiff problems.

### 1.5 Optimal Acceleration of High-Order Conservative Semi-Lagrangian Schemes in Graphics Cards Using CUDA

Julian T. Becerra-Sagredo, Carlos Malaga, Francisco Mandujano

EPFL, Switzerland; Science Faculty, UNAM, México

Graphic cards (GPUs) with a massive array of (many-core) multiprocessors are capable of one to two orders of magnitude more floating point operations per second than multi-core CPUs, along with large economic savings.

Semi-Lagrangian schemes for the solution of transport equations are suitable for acceleration in GPUs in an optimal manner. We present the texture-based implementation of a 5th order conservative semi-Lagrangian scheme using CUDA C language with examples of scalar transport, shallow-water equations and thermoacoustics, running live two orders of magnitude faster than the CPU version. We



discuss the problems and solutions to single precision calculation of high-order interpolations and the advantages of intense computation kernels combined with high bandwidth texture fetching.

## 1.6 Modelling and Simulation of Sap Flow and Heat Transport in Trees

**John Stockie**

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We investigate the flow of sap within a tree trunk, with a particular focus on issues specific to sap transport in the sugar maple, *Acer saccharum*. We begin by developing a model for sap flow within the porous, annular cylindrical region making up the sapwood of a tree. The flow is described in terms of a saturation variable obeying Richards' equation, along with saturation-dependent coefficients that capture the transport characteristics of the wood cells. We present simulations of sap flow during summer months, when sap is drawn upwards by a negative pressure gradient initiated by transpiration of water from the leaves. The numerical results are compared to experimental data taken from the literature.

During the winter sap harvesting period, no leaves are present to drive transpiration and the flow is driven instead by release of sap stored within the tree stem, initiated when daily temperatures begin to oscillate around the freezing point. We develop a separate model for heat transport within the tree trunk, which is driven by these daily temperature fluctuations that are of essential importance in maple sap flow. Because of the simple annular geometry, it is possible to derive an exact solution to the heat equation as a Bessel function series. We also perform numerical simulations using a finite difference approximation, and compare to our analytical results.

Finally, we consider the problem of coupling sap flow and heat transport. Numerical simulations are presented that give new insight into the importance of the various physical mechanisms. We also compare various sap harvesting strategies that have direct application to the maple sap industry.

## 1.7 A Non-Stiff Boundary Integral Method for 3D Porous Media Flow with Surface Tension

**Michael Siegel**

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An efficient, non-stiff boundary integral method for 3D porous media flow with surface tension is presented. Surface tension introduces high order (i.e., high derivative) terms into the evolution equations, which leads to severe stability constraints

for explicit time-integration methods. Furthermore, the high order terms appear in nonlocal operators, complicating the implementation of implicit methods. Our algorithm employs a special representation of the interface which enables efficient application of implicit time-integration methods via a small-scale decomposition. The algorithm is found to be effective at eliminating the severe time-step constraint that plagues explicit time-integration methods. This is joint work with David Ambrose (Drexel University).

## **1.8 Two and Three-Phase Flow in Porous Media: Mathematical, Numerical and Computational Models**

**Luis Miguel De la Cruz Salas**

GMMC, Depto. de Recursos Naturales

Geophysics Institute

Universidad Nacional Autónoma de México

Research on natural resources involves the study of two and three-phases flow models in porous media. Subsurface groundwater and oil reservoir systems are examples of these kinds of systems that can be modeled by a set of partial differential equations, complemented with constitutive and state equations. All these equations describe the dynamic behavior of the phases and their interaction with the rock systems where the fluids move.

Despite many mathematical and numerical models are available, it is not easy to take into account all the process that occur in an study of this sort. Besides, the existent commercial software is not adaptable to every one needs.

In this work a methodology to develop mathematical and computational modeling for two and three phase flows in porous media is presented. The mathematical models are obtained using an axiomatic formulation, which help us to obtain different models from a general and simple point of view. The numerical models are based on the finite volume method.

Several computational implementations are explained and the numerical results of some particular examples are presented. It is shown that the methodology can be applied to develop scientific software from scratch reusing components previously developed for other similar projects.

## **1.9 Applying Spectral Methods to Investigate the Instability if Shear Flows**

**Francis Poulin, Christopher Subich, Nick Chepurniy**

Department of Applied Mathematics, University of Waterloo

fpoulin@uwaterloo.ca

Shear flows are ubiquitous in the atmosphere and oceans and are of great importance in dis-tributing biological, chemical and physical properties. For example the atmospheric Jet Stream is responsible for a lot of variability in our daily weather and

the Gulf Stream in the Atlantic transports a large amount of heat north-eastwards thereby warming Europe.

Numerical simulations are the most powerful tool available to use to study shear flows since they allow us to accurately resolve the fully nonlinear dynamics over a vast range of length scales. In this talk we present recent work that investigates the stability of three-dimensional shear flows using two complimentary approaches. First, we solve the linear stability problem to determine the growth rates and structure of the unstable modes and how they depend on the various non dimensional parameters. This is done using a spectral collocation methods to discretize the eigenvalue problem. Second, we numerically simulate the fully nonlinear dynamics to determine what non-linear vortical structures are subsequently generated. This uses spectral extensions and the FFT. These calculations are done in parallel using MPI since this allows us to do the calculations in a reasonable amount of time.

### **1.10 Boundary integral simulations of separated flows and interfacial Stokes flows**

**Monika Nitsche**

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This talk will present two applications of boundary integral simulations of interfacial flows. The first regards the simulation of separated flow past oscillating plates, with application to locomotion. We study the dependence of the flow on the Strouhal numbers, the oscillation amplitude, and the waveform, and compare with viscous flow simulations. The second regards the evolution of drops and bubbles in Stokes flow. We address the numerical issues that arise for axisymmetric flows, and study the evolutions of bubbles immersed in a strain field. For a range of parameters, the bubbles approach a steady state. We classify the equilibria that arise for sufficiently small strainfield, and the non-steady motion for larger strain fields, including bubble pinchoff.

### **1.11 Fixed Grid Methods for Problems with (Moving) Interfaces**

**Huaxiong Huang**

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In this talk we will present some recent work for solving problems with (moving) interfaces on a fixed grid. We will discuss mainly the immersed boundary method for computing the motion of interfaces under the influence of (fixed or mobile) surface

agents. If time permits, a newly developed immersed boundary method for diffusion through permeabl interfaces will also be discussed.

## 2 Minisymposia-Optimization and Operations Research

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### 2.1 Convex Reformulations

**Yasmin A. Ríos Solís**

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Many optimization problems like just-in-time scheduling, territorial design or piece-mold machine manufacturing can be modeled with a quadric function subject to linear constraints and binary variables. The method we propose for solving these problems takes advantage of a well known result from 0-1 quadratic theory: convex quadratic programs with real variables subject to linear constraints can be efficiently solved.

By construction, the objective function of the quadratic program is often not convex (i.e., the Hessian matrix is not semidefinite positive). Then, we reformulate the quadratic program so that the new one is convex and has the same feasible solution space. In this way, we can solve the convexified program with a standard solver that is able to solve convex 0-1 quadratic programs by using a classical branch-and-bound algorithm based on continuous relaxations. Nevertheless, the behavior of the branch-and-bound algorithm strongly depends on the quality of the lower bound obtained at the root of the search tree.

In this work we use and propose different convex reformulation approaches. The aim is to obtain a tradeoff between finding the reformulation that maximizes the lower bound obtained by continuous relaxation and its computation time. The reformulation is achieved by perturbing in specific ways all terms of the Hessian matrix with two parameters that are obtained by solving associated semidefinite relaxations. Moreover, to improve the computational time we take advantage of the structure of the Hessian matrix.

Experimental results show out that this exact method (based on different convex reformulations) is in fact interesting and efficient. Moreover, for some problems we have, to the best of our knowledge, the best experimental results of the literature. For more details, we refer to M.-C Plateau and Y.A. Ríos-Solis, Optimal solutions for unrelated parallel machines scheduling problems using convex quadratic reformulations, *European Journal of Operational Research*, 201(3):729-736, 2010.

## 2.2 On the Nullstellensatz Method for Combinatorial Optimization

**Susan Margulies<sup>1</sup>**

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Unlike linear models, systems of multivariate polynomial equations over the complex numbers or finite fields can be compactly used to model combinatorial problems. In this way, a problem is feasible (e.g. a graph is 3-colorable, Hamiltonian, etc.) if and only if a given system of polynomial equations has a solution. In the work of M. Laurent, J. Lasserre and P. Parrilo, Y. Nesterov, and others, continuous optimization problems which are modeled by zero-dimensional radical ideals have been shown to have a finite sequence of semidefinite programs that converge to an optimal solution. For yes/no combinatorial decision problems (e.g., is a graph  $G$  3-colorable?), we observed that Hilbert's Nullstellensatz gives a sequence of *linear algebra* problems that eventually determines feasibility. This has advantages as linear algebra is quite stable on computation and sparsity is well-understood.

In this talk, we present theoretical and experimental results on these sequences of large-scale, sparse, linear algebra relaxations to the combinatorial optimization problem. We show that the size of the smallest Nullstellensatz linear algebra system certifying that there is no stable set of size larger than the stability number of the graph grows as the stability number of the graph. We additionally describe ideas for optimizing the method, such as utilizing alternative forms of the Nullstellensatz, adding carefully-constructed polynomials to the system, branching and exploiting symmetry. Finally, in the case of 3-colorability, we use this method to successfully solve graph problem instances having thousands of nodes and tens of thousands of edges.

## 2.3 New Results Concerning the Price of Anarchy

**Patrice Marcotte and Daoli Zhu**

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In a congested transportation system, equilibrium is reached when all users are assigned to shortest paths with respect to the current traffic conditions. This may lead to a loss of efficiency with respect to an assignment that minimizes total delay. In that context, the “price of anarchy” corresponds to the worst case ratio of the equilibrium delay over the optimal delay. In this presentation, we refine the results obtained by G. Perakis for the price of anarchy, and extend them to a bicriterion setting, where users have different monetary perceptions of the value of delay.

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<sup>1</sup>joint work with J.A De Loera, J. Lee, P.N. Malkin and S. Onn

## 2.4 Designing Routes for WEEE Collection: The Vehicle Routing Problem With Split Loads and Date Windows

José Luis González Velarde<sup>1</sup>, Julio Mar-Ortiz<sup>2</sup>, Adenso Díaz<sup>3</sup>

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This paper presents an integer programming model and describes a GRASP algorithm to solve a vehicle routing problem for the collection of Waste of Electric and Electronic Equipment (WEEE). Difficulty for this problem arises from the fact that it is characterized by four variants of the vehicle routing problem that have been studied independently in the literature but not together. The experimental analysis on a large set of randomly generated instances shows the convenience of the proposed algorithm.

## 2.5 MultiObjective Non-Linear Model Predictive Control of Chemical Reactors

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Traditionally process control has been widely used in the chemical industry for two main purposes: (1) Set-point tracking and (2) Disturbance rejection. When there is the need to operate chemical plants around optimal operating processing conditions a Real-Time optimization framework have been used. Then, optimal operating conditions are computed by the on-line optimization software and enforced as set-points to the control system. However, it has been recognized that by artificially splitting control and optimization tasks in two layers, the benefits of process optimization can be hard to achieve because of some implicit disadvantages in merging both approaches.

The aforementioned disadvantage can be removed by a simultaneous optimization and control approach where the task of the control system does not simply reduce to regulatory or servo tasks, but includes plant operation around optimality regions. In fact, some workers have reported real world experiences indicating impressive profit benefits when solving process optimization and control problems in an integrated or simultaneous manner. This is so because the simultaneous approach naturally exploits the interactions between optimization and control problems leading to better optimal operating regions and removing some of the communication problems between optimization and control software when used independently. However, most of the reported works on the simultaneous optimization and control approach have

relied on the use of a single objective function that may be inadequate to describe multiple optimization objectives. While the common way of handling multiple optimization problems reduces to combine them into a single objective function (using weighting functions) it is not always clear, and can be rather subjective, the way of assigning numerical values to the weighting functions. Our claim is that better optimal solutions can be obtained by solving the optimization problem by true multiobjective optimization techniques. Hence, the aim of this contribution lies in the proposal of a new simultaneous optimization and control nonlinear formulation able to take into account several objective functions while meeting all the constraints associated to the optimization formulation. The new nonlinear formulation is tested with a series of highly nonlinear semibatch chemical reactors.

## 2.6 Network Pricing under Elastic Demand

**Aimé Kamgaing Kuiteing, Patrice Marcotte, Gilles Savard**

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In the telecommunications or airline industries, network pricing lies at the core of the revenue management process. In this presentation, we consider elastic demand extensions of the generic network pricing model introduced by Labbé, Marcotte and Savard, i.e., the problem of maximizing the revenue raised from tolls set on a multicommodity transportation network, in the presence of rational customers that maximize their individual utility. We will present mixed integer formulations of the problem, in both path and arc flow spaces, when demand is affine. In the case of non linear demand, we have developed one exact and two heuristic algorithms. In the view that the quality of upper bounds previously obtained for the classical network pricing problem is notoriously bad, we have probed the efficiency of our heuristics against an improved upper bound. Both the properties of the models and numerical results will be presented.

## 2.7 A Consensus Model for Group Decision Support Based on Valued Outranking Relations

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In the group multicriteria decision aiding (GMCD) process, prior to the final solution to the ranking problem, it is desirable for decision makers to minimize the inconsistencies between the individual outranking relations and the associated final ranking and achieve a high degree of consensus or agreement between them. This



paper presents an order-based consensus model in group multicriteria decision aiding that proceeds from consistency-seeking to consensus-reaching. It is based on the use of valued outranking relations to model individual and group preferences. A consensus measure and proximity measure are defined; the first guides the consensus process and the second supports the group discussion phase of the consensus process. The degrees of consensus indicate how far a group of individuals is from the maximum consensus, and the proximity measure indicates how far each individual is from the current consensus.

Keywords: Consensus, Group Decision, Multiple Criteria Decision Analysis, Ranking Problem, Coordination Modes, Outranking Methods.

### 2.8 Alleviating the Impact of an Epidemic

**Ana Cecilia Zenteno**

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During an ongoing epidemic, systems such as health care institutions can become severely congested. Consider a finite resource (e.g. manpower) that can be used to alleviate such impact. For each day, one can decide how much of the resource to allocate; however, there is uncertainty as to the future course of the epidemic. We consider robust algorithms for intelligently rationing the resource, with an underlying SEIR model that tracks the epidemic. Joint work with Daniel Bienstock.

### 2.9 On a conjecture of C. Sundberg: A nonlinear programming based investigation

**Roland Glowinski & Annalisa Quaini**

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Following a lecture that the first author gave recently at UT-Knoxville, our colleague **Carl Sundberg** asked us if, using a computational approach, it was possible to find evidence of the validity of the following mathematical property:

$$\sup_{\varphi \in E} \frac{\int_0^1 \frac{|\varphi'|^4}{\varphi^6} dx}{1 + \int_0^1 |\varphi''|^2 dx} < +\infty \quad (SI)$$

where

$$E = \{\varphi | \varphi \in C^1[0, 1], \varphi'' \in L^2(0, 1), \varphi(0) = \varphi(1), \varphi'(0) = \varphi'(1), \varphi \geq 1\}$$

In this lecture we will describe the **augmented Lagrangian** based methodology we are using to investigate (SI), via appropriate **finite difference** discretizations of the cost function in (SI) and of the set E. The results of numerical experiments will be also presented; what they imply for the verification of (SI) will be commented.

## 2.10 A Mathematical Programming Approach to Pollution Trading

Vicente Rico-Ramirez<sup>1</sup>, Francisco López-Villarreal<sup>1</sup> and Urmila M. Diwekar<sup>2</sup>

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With environmental concerns being heightened, pollution abatement-related decisions are important for industry. Pollutant trading adds flexibility and introduces new options to policy makers and industries alike. Pollution trading is an approach to environmental protection that uses market based mechanisms to efficiently allocate emission or pollutant reductions among different sources. Early applications of trading were designed to provide greater flexibility for emission sources to meet air quality standards in a cost-effective manner. The overall goal is to meet environmental conditions equal or better than those obtained through pollutant treatment, but at a lower cost. Firms or organizations with financial capacity and infrastructure able to reduce their emissions below the required limits obtain credits. These credits can be sold to other firms to obtain financial benefits. Simultaneously, a firm which does not have the infrastructure capable to reduce its emissions can satisfy environmental regulations by purchasing credits. Credits can also be banked or accumulated to be used in future periods. Then, trading offers industries an option to satisfy the regulations at reduced costs. Individual industry level decisions affect the overall goal; such decisions are beyond heuristics and a systematic approach is needed.

This work proposes optimization models that can guide industries in taking optimal decisions under the added flexibility due to trading. The models can also guide regulators in developing optimal regulations in different situations. To assess the performance of the optimization models and explore the interesting aspects of environmental trading implementation, we consider a mercury trading case study. Different treatment technologies are considered (different cost and efficiency), and it is assumed that all of the technologies are available for every pollutant source. For simplicity, capital requirements and reduction capability of these technologies are related to the discharge volume. Total plant costs include capital as well as annualized operating costs per unit volume of discharge treated.

The mathematical models, formulated as mixed-integer programming problems, have been implemented and solved through the GAMS modeling environment. Results include optimal decisions for each pollutant source (industry); that is, either implementing one of the available pollution abatement technologies or attaining credits through trading. A comparison among the non-trading solution and the solutions of the various pollution trading models is presented and analyzed.

Keywords: Pollution trading, mathematical programming

## **2.11 Applied Optimization and Operations Research at the Centre for Operations Excellence**

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The Centre for Operations Excellence (COE), in the Sauder School of Business at the University of British Columbia, administers the Master of Management in Operations Research (MM in OR) program. The highlight of the MM in OR program is the Industry Project. Each student conducts an intensive 5-month applied project with a COE Industry Partner that addresses a significant operational issue. Working closely with faculty and COE project leaders, students apply operations research and other decision technologies, and deliver concrete tools and recommendations to senior executives of major organizations in the Pacific Northwest. We will outline some of the recent industry projects with significant applied optimization or operations research contents.

## **2.12 Efficient Territory Design Planning by a Novel Location-Allocation-Improvement Algorithm**

**Roger Z. Ríos-Mercado<sup>1</sup>, Ada M. Álvarez<sup>2</sup>, Karim de Alba<sup>3</sup>, J. Ángel Segura-Ramiro<sup>4</sup>**

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Territory design is the problem of grouping small geographic areas called basic areas (e.g., counties, zip code areas) into larger geographic clusters called territories such that the latter fulfill relevant planning criteria. These criteria can either be economically motivated (e.g., average sales potentials, workload, number of customers) or have a demographic background (e.g., number of inhabitants, voting population). Moreover, spatial restrictions, like compactness or contiguity, are often demanded. Territory design problems are motivated by very different applications, ranging from political districting over the design of territories for waste collection to sales and service territory design.

In particular, in this talk a commercial territory design problem motivated by a real-world application from a bottled beverage distribution firm is presented. The problem consists of finding a set of territories subject to contiguity, compactness, and multiple balance requirements with respect to each node activity measure. After presenting a description of the problem and a discussion of its associated model, a proposed solution approach based on a novel location-allocation scheme is described in detail. The talk will include an evaluation of the proposed method in a variety of data instances, and a discussion of problem extensions and a broader class of unexplored territory design problems.

### 2.13 Optimality of the Neighbor Joining Algorithm and Faces of the Balanced Minimum Evolution Polytope

**Ruriko Yoshida**

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Balanced minimum evolution (BME) is a statistically consistent distancebased method to reconstruct a phylogenetic tree from an alignment of molecular data. It is a weighted least-squares solution that puts more confidence on shorter distances than longer ones. In 2008, Eickmeyer et al. showed that BME method is equivalent to optimizing a linear function, the dissimilarity map, over the BME polytope defined as the convex hull of vectors obtained from Pauplin's formula applied to all binary trees. In this talk, we first show that any subtree-prune-regraft move from a binary tree to another binary tree corresponds to an edge of the BME polytope. Moreover, we describe an entire family of faces parametrized by disjoint clades, clades-faces, which are smaller dimensional BME polytopes themselves. Then we show that for any choice of picking neighbors (cherries), there exists a distance matrix such that the Neighbor-Joining algorithm returns the BME tree. This is joint work with David Haws and Terrell Hodge.

### 3 Minisymposia-Inverse Problems and Control

#### 3.1 Chaotic Gradient Descent Methods

**Kees van den Doel**

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The conjugate gradient (CG) algorithm is usually the method of choice for the solution of large symmetric positive definite linear systems  $Ax = b$ . If however the matrix-vector products  $Av$  required at each iteration can not be calculated accurately, the delicate mechanisms on which CG is built can be easily disturbed and cause disaster. In such cases we may consider gradient descent methods, which are more robust against such effects.

The classical steepest descent (SD) method, which takes the best possible (greedy) step in terms of reducing the error at each iteration, is well-known to wiggle agonizingly slowly to the solution. Fortunately its behavior improves dramatically (by orders of magnitude) by some tinkering with the step size. This has given rise to a zoo of fast gradient descent methods known as BB, LSD(s), HLSD(k), SDOM, SD( $\omega$ ) etc. These methods are in practice much closer to CG in performance than to SD (though nobody has been able to prove this) and can outperform CG under certain conditions.

I will present numerical experiments to establish which of the methods perform best on average, then show that the fast gradient descent methods generate chaotic dynamical systems. Very little is required to generate chaos here: simply damping steepest descent by a constant factor close to 1 will do. Some insight will be given into how chaos speeds up these methods, and I will show beautiful animations of the chaotic dynamics.

#### 3.2 On an Inverse Problem for the Nonlinear Wave Equation

**Miguel A. Moreles, Marcos A. Capistrán**

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In this paper we address the inverse problem of reconstructing the non-constant propagation speed of a wave from measurements of the solution of the non-linear, one-dimensional wave equation. We define a wave-speed-to-solution map and pose the inverse problem as a classical non-linear least squares optimization problem restricted to the continuous equation. Using the adjoint equation method we efficiently compute the derivative of the least squares functional with respect to the wave speed and consequently implement the L-BFGS algorithm to solve the inverse problem locally. We offer some numerical examples with synthetic data.

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### 3.3 Stochastic Collocation for Optimization Problems Governed by Stochastic Partial Differential Equations

**Drew Kouri**

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Many optimization problems in engineering and science are governed by partial differential equations with uncertainties in the input data. We refer to these governing equations as stochastic partial differential equations (SPDEs). Since the solution of such a SPDE is a random field and enters the objective function, the objective function usually involves statistical moments. Optimization problems governed by SPDEs are posed as a particular class of optimization problems in Bochner spaces. This allows us to use the framework for derivative based optimization methods in Banach spaces. However numerical solution of these problems is more challenging than deterministic PDE constrained optimization problems, because it requires discretization of the SPDE in space/time as well as in the random variables. We discuss stochastic collocation methods for the numerical solution of such optimization problems, explore the decoupling nature of this method for gradient and Hessian computations, and present estimates for the discretization error. In addition, for a class of time dependent problems we show how balanced truncation model reduction can be used to dramatically reduce the size of the discrete problems.

This is joint work with M. Heinkenschloss.

### 3.4 Optimal Control Problems in Insurance and Finance

**Huaxiong Huang**

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In this talk we will present some recent work for solving optimal control problems with application in insurance and finance. We will discuss the problem of retirement planning and the effect of mortality risk. We will also discuss some analytical and numerical issues related to the solutions of these type of problems.

### 3.5 Identification of a Pressure Dependent Heat Transfer Coefficient

**A. Fraguera<sup>1</sup>, J. A. Infante<sup>2</sup>, A. M. Ramos<sup>2</sup>, J. M. Rey<sup>2</sup>**

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In this work, we focus our attention on an inverse problem concerning the identification of the heat transfer coefficient  $H$  (assuming it depends on pressure) between a certain material with the external environment. Some practical applications in which this coefficient appears can be seen in [1], [2], [3] and [4]). The goal is to identify  $H$  to get a solution for the corresponding model, approximating some given temperature measurements. The physical problem modeled in the references mentioned above is the evolution of the temperature in a homogeneous sample of a material placed in an equipment capable of compressing it (which will increase its temperature) and, that is also warming up (respectively, cooling down) due to heat exchange with an external environment that is warmer (respectively, cooler). For simplicity, let us consider an homogeneous sample and let us assume that the temperature gradient inside it is negligible. The Newton Cooling Law and the relation describing the change in temperature due to the pressure variation, when isentropic changes of temperature are assumed (see [4]), provide a simple mathematical model for this phenomenon through the following initial value problem (direct problem)(1):

Here  $T(t)$  (K) is the temperature of the sample at time  $t$ ;  $P(t)$  (Pa) is the pressure of the equipment at time  $t$ ;  $T_a$  is the ambient temperature;  $T_0$  is the temperature at the initial time;  $c$  is specific heat capacity; and  $H$  is the pressure dependent heat exchange coefficient. In order to solve problem (1), constants  $T_a$ ,  $T_0$ ,  $c$ , pressure  $P$  and function  $H : [P_{\min}; P_{\max}]$  are needed ( $[P_{\min}; P_{\max}]$  is a suitable range of pressure). The values of  $T_a$  and  $T_0$  can be obtained by measuring devices (thermocouples), the coefficient  $c$  is assumed to be known and the pressure is provided by the equipment. However, function  $H$  cannot be obtained easily. We will design strategies to enable, from experimental measurements, the identification of function  $H$  (inverse problem).

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### 3.6 A Stochastic Newton Method for Large-Scale Statistical Inverse Problems

**Omar Ghattas**

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We are interested in the solution of several inverse problems in solid earth geophysics, including the inference of mantle constitutive parameters from observed plate motions, earth seismic velocities from surface seismograms, and polar ice sheet basal friction from satellite observations. Each of these inverse problems is most naturally cast as a large-scale statistical inverse problem in the framework of Bayesian inference: given observations and their uncertainty, the governing PDEs and their uncertainty, and a prior model of the parameter field and its corresponding uncertainty, find the posterior probability density of the parameters.

The posterior density is a surface in high dimensions, and the standard approach is to sample it via a Markov-chain Monte Carlo (MCMC) method and then compute statistics of the samples. However, standard MCMC methods view the underlying parameter-to-observable map as a black box, and thus do not exploit PDE structure. As such, these methods become prohibitive for high dimensional parameter spaces and expensive-to-solve PDEs.

Here, we present a Langevin-accelerated MCMC method for sampling high-dimensional, expensive-to-evaluate probability densities. The method builds on previous work in Metropolized Langevin dynamics, which uses gradient information to guide the sampling in useful directions, improving acceptance probabilities and convergence rates. We extend the Langevin idea to exploit local Hessian information, leading to what is effectively a stochastic version of Newton's method. We apply the method to the Bayesian solution of a seismic inverse problem, for which we observe several orders of magnitude faster convergence over a reference blackbox MCMC method.

Joint work with Tan Bui-Thanh, Carsten Burstedde, James Martin, Georg Stadler, and Lucas Wilcox.



### 3.7 Level Set Regularization for Highly Ill-Posed Distributed Parameter Estimation Problems

**Uri Ascher**

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(Joint work with Kees van den Doel)  
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We consider inverse problems of surface recovery from noisy boundary data, where the forward problem involves the inversion of elliptic PDEs. Instances arise in electromagnetic data inversion, impedance tomography, potential problems and computed myography. Special challenges arise when the surface has discontinuities, and we then consider reduced problems of shape recovery.

The piecewise constant solution, a scaling and translation of characteristic functions, is described in terms of a smoother level set function. We propose a fast and robust dynamic regularization method for this purpose. For problems of moderate size in 2D, direct linear algebra methods have been found rather effective. For larger problems, especially in 3D, iterative methods are required. Perhaps contrary to initial intuition, the iterative methods are particularly useful for the inverse rather than the forward linear systems. Preconditioned conjugate gradient methods are investigated for the inner iteration of a Gauss-Newton outer loop and the efficacy of the obtained scheme is demonstrated.

### 3.8 Automatic Correction of the Personal Orientation in Space

**V.V. Alexandrov<sup>1,2</sup>, W. Fermín Guerrero Sánchez<sup>1</sup>, M. Gutiérrez Arias<sup>1</sup>, M. Reyes Romero<sup>1</sup>**

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This study is aimed to developing of a new research profile in biomechatronics with approach in the spatial personal orientation. The personal orientation involves a complex integration of exteroceptive, vestibular, and visual sensory information. Healthy people maintain an efficient control of body posture which is equally important for standing and walking, as well as for providing support for voluntary limb movements and thereby properly orient and move in space. It is known that land animals the vestibular system plays an important role initiating postural reflexes to align the head and trunk making it possible to maintain the posture. The diminution of vestibular system capabilities to provide information about the influence of gravity and inertial forces produced during head movements is causing of higher of risk probability of falling and loss of orientation. Advances in electronics open up the possibility to develop simulation devices of vestibular function to operate as

automatic amender of the vertical posture. To contribute with the development and testing of these devices, we have developed a mathematical model for the generation of signals from vestibular mechanoreceptors (vestibular system). The progress in the development of this model, which simulates a fundamental part for the equilibrium of vertical position, give the option of designing devices that function as evaluators and automatic correction, in many situations, of personal orientation in space. We approach five main areas of study in progress within of this line of research. The first topic to which we refer is related to vehicles that are controlled with both an automatic mechanism and a driver. There are simulators to test drivers, drivers also tested the vehicles, as well as possible using dynamic simulators (simulator of a driver) to approve the semi-automatic quality control vehicles. For testing quality semi-automatic stabilization in extreme conditions we are designing a "maximin" algorithm.

Currently such an algorithm is used to train the leaders of the baggage of spacecraft "Soyus-TM" to travel to the International Space Station. The idea is to reduce a problem of "maximin" to a "geometrical game" and finding the saddle point, if this point does not exist, then the alternative is to build a "mixed strategies (stochastic)". A second issue related to the ability of drivers is the study of information processes in the inertial mechanoreceptors to personal orientation of pilots inspace. To perform these investigations is necessary to obtain mathematical models of information processes in inertial mechanoreceptors of the vestibular apparatus, the modeling of these processes has been complex due to the integration of three levels of description - macro, micro (cellular) and nano (molecular) - . The third topic, as a first application of mathematical modeling of bio-inertial sensors, is the design of automatic correction algorithm for stabilization of gaze in the horizontal plane, to evaluate this algorithm can be used simulators and the maximin algorithm. The fourth issue, as a second application, is about a proposal for vestibular prosthesis prototype for older adults and vestibular disabled. Now we have an automatic algorithm correction of vertical position. According to our previous investigations is possible the fifth case study, the feasibility to design and construction of a prototype dynamic simulator to approve automatic rectifiers of personal orientation (hereafter we refer to it as dynamic simulator). The dynamic simulator consists of two imitators, a mobile mimic of vertical posture and a simulator of vestibular function which we defined as MEMS (Micro-Electro-Mechanical Systems) of vestibular function. With the dynamic simulator is possible to achieve a comparative analysis of the response of a vestibular prosthesis prototype and the response of MEMS vestibular function when the vestibular prosthesis prototype is placed on the dynamic simulator and it is subjected to extreme situations, the process of locating and evaluating the response of the prototype we have appointed pre-clinical testing in extreme situations of the fall. The strategy for these extreme situations is a synthesis of two self-oscillations with different limit cycles, derived from solving a maximum deviation problem for the mobile simulator of vertical posture.

### 3.9 Model Reduction for Decision Under Uncertainty

**Karen Willcox**

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Stochastic optimization/control for systems governed by PDEs presents a significant challenge. The discretized forward models describing such systems typically are of very high dimension and are expensive to solve, and the number of parameters representing the optimization decision variables may be large. The computational resources required to solve a stochastic optimization problem therefore quickly become prohibitive. Model reduction can address these challenges by producing low-order approximate models that retain the essential dynamics but that are fast to solve. We describe recent progress in goal-oriented model reduction methods that are informed by the stochastic optimization problem. Our methods use state approximations through the proper orthogonal decomposition, reductions in parameter dimensionality through parameter basis approximations, and the empirical interpolation method for efficient evaluation of nonlinear terms.

### 3.10 Numerical Methods for Seismic Inversion

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Seismic technologies for imaging the earth's surface have advanced to the stage where it is feasible to solve for physical parameters of geological structures deep within the earth. Successful exploration for oil and gas reservoirs depends on determining rock properties such as density, porosity, presence of fluids and gases, among others.

We present results from recent work on instructive 1D models and progress in 2D models, that demonstrate effective numerical methods to recover model parameters in the PDE representation of elastic seismic wave propagation in the earth. A comparison of regularized least squares and  $\ell^1$  sparse methods will be given.

This is joint work with Dr. G. Margrave, in the POTSI project of the MITACS NCE.

### 3.11 Solution of Direct and Coefficient Inverse Problems for Partial Differential Equations by General Ray Method

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It is presented a new approach for solution of: 1) direct boundary value problems for the elliptic and parabolic partial differential equations; 2) coefficient inverse problems for the Laplace type and parabolic equations.

A new approach for the solution of boundary value problems on the base of the General Ray Principle (GRP) was proposed by the author in [1] for the stationary waves field. The GRP means to construct for considering partial differential equations (PDE) an analogue as a family of ordinary differential equations (ODE), describing the distribution of the wanted solution along of "General Rays", which are presented by a straight line with the traditional Radon parameterization. GRP leads to GR-method that presents solution by explicit analytical formula. The t-version of GR-method was constructed in [1, 2]. It consists in reducing PDE to the assemblage of ODE with respect to variable  $t$  due the direct substitution of functions and derivatives by their traces. The numerical justification of t-version of GR-method was given for the domain as unit circle [1]. For some convex domains the quality of the method was illustrated by numerical examples. The reduction of the considered PDE to the family of ODE with respect to variable  $t$  gives possibilities to satisfy directly boundary conditions, construct the effective and fast numerical algorithms. At the same time, there are problems with its realization for no convex domains.

Another, p-version of GR-method, constructed by the author in [3], is based on application of the Radon transform directly to the PDE. This version of GR-method can be used for any simple connected star domain. It is justified theoretically, realized as algorithms and program package in MATLAB system, illustrated by numerical experiments that confirm more rapidity of new method in comparison of finite element method [4].

For solution of coefficient inverse problems for the Laplace type equation and parabolic equation with variable coefficient we proposed approach and statement that use GRP. Traditional approach for solving such inverse problems leads to a nonlinear ill-posed problems. Constructed for this type of problems t-version of GR-method gives solutions by explicit analytical formulas and can be used for solution of some applied problems [5, 6].

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### 3.12 Aerodynamic Shape Optimization Under Uncertainties

**Volker Schulz**

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In this talk, we discuss a novel approach towards stochastic distributed aleatory uncertainties for the specific application of optimal aerodynamic design under uncertainties. Besides the scalar valued uncertainties in flight conditions we consider the shape itself as an uncertainty source. We consider the mean value of the objective function as a risk measure, whereas the constraints are required to hold for all realizations of the uncertain parameters. Due to the highly nonlinear underlying design problem, polynomial chaos methods are used in order to approximate and consequently simplify the problem to a solvable optimization task. The Gaussian random field describing the geometrical uncertainties on the shape is approximated by a Karhunen-Loeve expansion, based on a spectral decomposition of the covariance kernel, which leads to a representation of the random field in a finite number of random variables. To further reduce the computational effort, the Karhunen-Loeve basis is chosen goal-oriented by the use of first order derivative information. To overcome the curse of dimensionality an adaptively refined sparse grid is applied in order to determine the Polynomial chaos expansion and hence statistics of the objective function with respect to the uncertainties. Finally, algorithmic approaches based on multiple-setpoint ideas in combination with one-shot methods will be presented as well as numerical results.

## 4 Minisymposia-Applied Probability and Statistics

### 4.1 Geometric Stick-Breaking Processes for Continuous-Time Nonparametric Modeling

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This talk is concerned with the construction of a continuous parameter sequence of random probability measures and its application for modeling random phenomena evolving in continuous time. At each time point we have a random probability measure of the stick-breaking type and with dependence structure driven by a Wright-Fisher diffusion process. The sequence is shown to be a stationary and reversible diffusion taking values on the space of probability measures. A simple estimation procedure for discretely observed data is presented and illustrated with simulated and real data sets.

### 4.2 Performance of WiFi Protocols

**David McDonald**

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The Wi-Fi protocol or IEEE 802.11 is a distributed media access algorithm commonly used to optimize the utilization of shared bandwidth by multiple users. The key idea is exponential back-off. If the transmissions of two users collide they both reduce their probability of transmitting in the next time slot by half. On the other hand if a user transmits successfully it increases its transmission probability to a maximal value. Consequently a system with  $N$  users is a complicated dynamical system of user transmission probabilities with interaction. We can estimate the performance of this system by finding the associated mean field limit of the histogram of transmission values.

Unfortunately it is well known that the standard exponential back-off algorithm used in IEEE 802.11 does not guarantee short term fairness between flows. Recently protocols like Idle Sense have been proposed to reduce this short term unfairness by having each flow adaptively find the optimal probability  $p^*$  of accessing the channel in the next empty time slot. We consider a modification called **Lock Step** where each flow tries to transmit every  $W = 10N$  slots; i.e. 10 slots per flow with 9 idle. Each flow adaptively adjusts its window  $W$  based on the observed proportion of empty slots over the last transmission round. One key aspect of the algorithm is to set a deterministic back-off after a successful transmission so that eventually all users are in lock step and transmit every  $10N$  slots. Packets are transmitted at much more regular intervals and we can substantially increase the number of flows carrying Voice over IP traffic through a single access point.

### 4.3 Some Counting Processes to Study Ozone Air Pollution

**Eliane R. Rodrigues**

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In this talk we consider the problem of studying the probability of a given threshold being surpassed a certain number of time by an ozone concentration measurement, i.e., we are analysing the number of times that an exceedance occurs. We consider some counting processes to analyse that. First, we use a non-homogeneous Poisson model with a rate function that depends on some parameters that need to be estimated. Secondly, we assume that the inter exceedance times are ruled by a Gamma distribution (independent and dependent). In the second case, the distribution of the inter exceedance times also depends upon some parameters that need to be estimated. The estimation of the parameters are performed using a Bayesian formulation via a Markov chain Monte Carlo algorithm. The results are applied to the data provided by the monitoring network of Mexico City. This talk is part of joint works with J. A. Achcar, M. Tarumoto and G. Tzintzun.

### 4.4 Spatio-Temporal Model for Lightning Caused Forest Fire Ignitions, using Shotnoise Cox Point Processes

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Spatio-temporal Cox point process models with a multiplicative structure for the driving random intensity, incorporating covariate information into temporal and spatial components, and with a residual term modelled by a shot-noise process, are a flexible and tractable model class for statistical analysis, using spatio-temporal versions of intensity and inhomogeneous K-functions, quick estimation procedures based on composite likelihoods and minimum contrast estimation, and easy simulation techniques. These advantages are demonstrated in connection to the analysis of a relatively large dataset consisting of 2796 days and 5834 spatial locations of fires in the Blue Mountains, Oregon.

Keywords: Continuous-time dependent random measure, Markov process, measure-valued process, stationary process, stick-breaking process.

### 4.5 The Expected Gerber-Shiu Penalty Function for Classical Risk Processes Perturbed by $\alpha$ -Stable Processes

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The classical risk process is given by  $U(t) = u + ct - \sum_{k=1}^{N(t)} X_k$ , where  $N(t)$  is a homogeneous Poisson process with intensity  $\lambda$ , the claim sizes  $X_1, X_2, \dots, X_n, \dots$

are i.i.d., initial capital  $u \geq 0$ , and premium rate  $c$ . The ruin probability, as a risk measure, is an important functional for the risk processes.

In order to model big fluctuation for the capital, Furrer introduced the perturbed risk process:  $X_\alpha(t) = U(t) + \eta W_\alpha(t)$ ,  $1 < \alpha \leq 2$ ,  $\eta \geq 0$ , where  $W_\alpha(t)$  is a standard  $\alpha$ -stable process without positive jumps, independent of  $U(t)$ , and obtained an explicit expression for the ruin probability.

The expected discounted penalty function of Gerber-Shiu is given by the formula  $\varphi(u) = E[\exp(-\delta T)w(X_\alpha(T-), |X_\alpha(T)|) \times I(T < \infty) | X_\alpha(0) = u]$ ,  $u \geq 0$ , where  $T$  is the ruin time,  $\delta$  is a constant, and  $w(x, y) : \mathbb{R}_+ \times \mathbb{R}_+ \rightarrow \mathbb{R}_+$  is a nonnegative function.

In this work we obtain the Laplace transform of the Gerber-Shiu expected discounted penalty function for the Furrer's model. As a particular case we give expressions for severity of ruin, the moments of the surplus at ruin time and recover the Furrer's formula for the ruin probability.

## 4.6 Phase-Type Distributions and Heavy Tails

**Mogens Bladt**

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Phase-type distributions is a flexible class of distributions which has been used extensively in risk and queueing theory. They are defined as the distribution of the time until absorption in Markov jump processes with finitely many states, one of which is absorbing and the rest being transient. Phase-type distributions often allows for explicit and/or exact solutions in complicated stochastic models, and their generality stems from the fact that they may approximate any distribution on the positive reals. In spite of this denseness property, their tails are light being exponentially decaying, which somewhat limits their use when modeling heavy tailed phenomena in which the tail behavior is of importance as for example when dealing with ruin probabilities. In this talk we introduce a class of infinite dimensional phase-type distributions, which may also be heavy tailed. Basic construction of e.g. Pareto type phase-type distributions is outlined and an example from risk theory concerning the calculation of exact ruin probabilities is presented.



## 5 Minisymposia-Numerical Analysis and Lineal Algebra

### 5.1 Numerical Solution of a Nonlinear Matrix Equation Arising in Nano Research

**Chun-Hua Guo, Yueh-Cheng Kuo, Wen-Wei Lin**

The matrix equation  $X + A^T X^{-1} A = Q$  arises in Green's function calculations in nano research, where  $A$  is a real square matrix and  $Q$  is a real symmetric matrix dependent on a parameter and is usually indefinite. In practice one is only interested in those values of the parameter for which the matrix equation has no stabilizing solutions. The solution of interest in this case is a special weakly stabilizing complex symmetric solution  $X_*$ , which is the limit of the unique stabilizing solution  $X_\eta$  of the perturbed equation  $X + A^T X^{-1} A = Q + i\eta I$ , as  $\eta \rightarrow 0^+$ . We show that a doubling algorithm can be used to compute  $X_\eta$  efficiently even for very small values of  $\eta$ , thus providing good approximations to  $X_*$ . It has been observed by nano scientists that a modified fixed-point method can sometimes be very efficient, particularly for computing  $X_\eta$  for many different values of the parameter. We provide a rigorous analysis of this modified fixed-point method and its variant, and of their generalizations.

### 5.2 A Multi-level Full Approximation Scheme in Space and Time

**Michael Minion**

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I will discuss an iterative temporal integration approach for time-dependent partial differential equations, which employs a multi-level strategy in both the spatial and temporal dimensions. The overall method is a space-time extension of the Full Approximation Scheme multi-grid method for nonlinear problems. The iteration or “relaxation” operator in the temporal direction is based on deferred correction methods. I will give numerical examples of the efficiency and accuracy of the multi-level approach and demonstrate how it can be employed to create efficient space-time parallel methods.

### 5.3 New Functional for Improving the Distribution of the Area of the Cells in Plane Structured Grids

**Pablo Barrera-Sanchez, Guilmer F. Gonzalez Flores**  
Facultad de Ciencias -UNAM

In this talk we present a new functional for structured grid generation in irregular plane regions that allows to improve the distribution of the area of the cells of the

grid. We present some of the ideas behind the construction and some results in a new version of our system UNAMALLA. We will use these functional in a module for grid generation in 3D that will be used in a Numerical Simulator for Oil Reservoirs that we are building for PEMEX.

#### 5.4 New Rigorous Perturbation Bounds for Cholesky, LU and QR Factorizations

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Two types of approaches have been used to derive normwise perturbation bounds for Cholesky, LU and QR factorizations, which are fundamental tools in matrix computations. One is the matrix-vector equation approach and the other is the matrix equation approach. The matrix-vector equation approach usually gives sharp first-order or rigorous bounds, but the bounds are expensive to estimate and the conditions for the rigorous bounds to hold are often too restrictive and complicated. The matrix equation approach comes in two flavours. The classic matrix equation approach gives first-order or rigorous bounds, which can be efficiently estimated and the conditions for the rigorous bounds to hold are less restrictive and simpler. But the bounds are usually not tight. The refined matrix equation approach, which uses row or column scaling techniques, has been mainly used to derive first-order bounds, which are often good approximations to the sharp first-order bounds derived by the matrix-vector equation approach and can be efficiently estimated. A remaining question, which is important in both theory and practice, is are there rigorous perturbation bounds which are tight, can be efficiently estimated, and need only moderate conditions to hold? This talk gives a positive answer to this question by using a combination of the classic and refined matrix equation approaches. We will use the QR factorization as an example to illustrate the main ideas.

This is joint work with Damien Stehlé.

#### 5.5 Krylov Subspace Recycling with an Application to Acoustics

**Eric De Sturler**

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In many computational science and engineering problems, we have to solve a sequence of large, sparse, linear systems, in which the matrix changes slowly from one system to the next or changes in an algebraically structured way. The right hand side can change more drastically, although in many applications this is not the case. We have developed several methods that significantly improve the convergence of iterative solvers by recycling from one system to the next a judiciously selected

subspace of the search space, for example an approximate invariant subspace, but other possibilities have proven effective as well.

After discussing the general principles of Krylov subspace recycling, we will focus on a problem involving internal and external acoustics and demonstrate how recycling can reduce the total number of iterations for the sequence of linear systems in a frequency sweep by a significant factor.

This is joint work with Jan Biermann, Technische Universität Hamburg-Harburg.

## **5.6 Some Results in Solving Partial Differential Equations on Irregular Spatial Domains Using Finite Differences Schemes and Logically Rectangular Grids**

**Jose-Gerardo Tinoco-Ruiz, Francisco-Javier Dominguez-Mota**

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In the last two decades there have been important advances in grid generation. At the moment, several authors have designed methods to construct good grids over irregular plane regions: grids featuring desirable geometrical properties such as orthogonality, smoothness and area control. Particularly, in Mexico the UNAMALLA group has obtained excellent theoretical and practical results using the direct approach to generate logically rectangular meshes.

The motivation to generate this kind of grids was to use them, in combination with finite differences schemes, to approximate the solution of partial differential equations defined over extremely irregular regions, as an alternative to the widely used finite element method. However, up to our knowledge, there are few results in this direction; we can mention the works of Shashkov, Steinberg, Benito et al., as well as some of our own.

In this talk, we will do some review of several methods for elliptic PDE's, including some recent ones, developed by us. We will compare their performance, using for benchmarking a standard finite element method. Some advances will be presented for the parabolic case.

## **5.7 Orbit Continuation for Computing Stable/Unstable Manifolds**

**Eusebius Doedel**

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We demonstrate the remarkable effectiveness of numerical continuation and boundary value formulations of the problem of computing stable and unstable manifolds of equilibria and periodic orbits in ODE systems. The main example will be the Circular Restricted Three-Body Problem, which models the motion of a satellite in an Earth-Moonlike system. In particular we compute the unstable manifold of

periodic orbits known as Halo orbits, which have been used in actual space missions. Our calculations lead to the detection of heteroclinic connections from Halo orbits to invariant tori. Subsequent continuation of such connections (as the Halo orbit is allowed to change) leads to a variety of connecting orbits that may be of interest in space-mission design.

## 5.8 Stability of GMRES Convergence and Approximate Preconditioning

**Mark Embree**  
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How does the convergence of the GMRES method for solving the linear system  $Ax = b$  change when the coefficient matrix  $A$  is perturbed to  $A + E$ ? Since this perturbation can introduce considerable changes to the spectrum of  $A$ , the conventional analysis of GMRES based on eigenvalues and diagonalization does not provide much insight. We propose an alternative approach that exploits the robustness of the resolvent norm to perturbations, using a general technique that dates back to Rinehart (1956).

This approach is most useful when applied to preconditioned problems. Often an idealized preconditioner is amenable to analysis, but is not practical to implement. Our bounds can quantify how much an inexact applied preconditioner can lag behind the performance expected of the exact preconditioner. We illustrate this application in two different settings: approximate deflation preconditioning (where the exact eigenvalues required of the ideal preconditioner are replaced by Ritz values) and the inexact application of the Murphy, Golub, Wathen preconditioner for saddle point problems.

This talk describes collaborative work with Ronald Morgan, Josef Sifuentes, and Gilbert Ymbert.

## 5.9 Clusters in the Helbing's Improved Model

**Patricia Saavedra<sup>1</sup>, Rosa María Velasco<sup>2</sup>**  
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<sup>2</sup>Physics Department

The macroscopic traffic flow models represent a possible approach to study vehicle behavior in a highway. They are based on an analogy between compressible flow in a Navier-Stokes fluid and the traffic flow. In this work we have chosen the improved Helbing's model [1] which considers the continuity equation for the density  $\rho(x, t)$ , the equation describing the average speed  $V(x, t)$  and, the speed variance equation  $\Theta(x, t)$ . This model introduced the length of vehicles as well as a safe distance between them and experimental information is used to calculate them. Numerical results show that in a closed circuit traveling waves are formed. This

work concerns the analysis through an iterative method of the formation of clusters in Helbing's improved model. It is shown that after certain density we will always obtain a density profile which has the structure of a soliton. Its characteristics such as the amplitude and width are determined by the parameters in the model.

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## **5.10 An Analysis of Low-Rank Modifications of Preconditioners for Saddle Point Systems**

**Chen Greif<sup>1</sup>, Michael L. Overton<sup>2</sup>**

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We characterize the spectral behavior of a primal Schur-complement-based block diagonal preconditioner for saddle point systems, subject to low-rank modifications. This is motivated by a desire to reduce as much as possible the computational cost of matrix-vector products with the (1,1) block, while keeping the eigenvalues of the preconditioned matrix reasonably clustered. The formulation leads to a perturbed hyperbolic quadratic eigenvalue problem. We derive interlacing results, highlighting the differences between this problem and perturbed linear eigenvalue problems. As an example, we consider primal-dual interior point methods for semidefinite programs, and express the eigenvalues of the preconditioned matrix in terms of the centering parameter.

## **5.11 Algebraic Optimizable Schwarz Methods for the Solution of Banded Linear Systems and PDEs on Irregular Domains**

**Daniel B. Szyld**

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Classical Schwarz methods and preconditioners subdivide the domain of a partial differential equation into subdomains and use Dirichlet or Neumann transmission conditions at the artificial interfaces. Optimizable Schwarz methods use Robin (or higher order) transmission conditions instead, and the Robin parameter can be optimized so that the resulting iterative method has an optimal convergence rate. The usual technique used to find the optimal parameter is Fourier analysis; but this is only applicable to certain domains, for example, a rectangle.

In this talk, we present a completely algebraic view of Optimizable Schwarz methods, including an algebraic approach to find the optimal operator or a sparse approximation thereof. This approach allows us to apply this method to any banded

or block banded linear system of equations, and in particular to discretizations of partial differential equations in two and three dimensions on irregular domains. This algebraic Optimizable Schwarz method is in fact a version of block Jacobi with overlap, where certain entries in the matrix are modified.

With the computable optimal modifications, we prove that the Optimizable Schwarz method converges in two iterations for the case of two subdomains. Similarly, we prove that when we use an Optimizable Schwarz preconditioner with this optimal modification, the underlying Krylov subspace method (e.g., GMRES) converges in two iterations. Very fast convergence is attained even when the optimal operator is approximated by a sparse transmission matrix. Numerical examples illustrating these results are presented.

### 5.12 Computation of Matrix Functions using the Hadamard Product

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We present an algorithm for the computation of functions  $f(tA)$ , where  $A$  is a square matrix,  $t$  is a real or complex variable, and  $f$  is a function defined on the spectrum of  $A$ . We compute first a function  $h(t)$  that depends on the minimum polynomial of  $A$  and then the function  $(I - tA)^{-1}$ . The Hadamard product of this function and  $f(t)$  gives  $f(tA)$ . The eigenvalues of  $A$  are not needed. We present some numerical results for  $\exp(tA)$ .

### 5.13 A Simple Technique for Solving Partial Differential Equations on Surfaces

**Steve Ruuth**

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Many applications require the solution of time-dependent partial differential equations (PDEs) on surfaces or more general manifolds. Methods for treating such problems include surface parameterization, methods on triangulated surfaces and embedding techniques. This talk considers an embedding approach based on the closest point representation of the surface which is very general with respect to the underlying surface and PDE, yet is extremely simple. Recent applications to high-order PDEs and Laplace-Beltrami eigenmodes are given to illustrate the approach.

This talk describes joint work with Colin Macdonald (Oxford) and Barry Merriman (UCLA).

## 5.14 Edge Detection by Normalized Cut and Power Method, and an Application to Motion Detection

**Humberto Madrid**

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This work begins with a short discussion of a graph partitioning technique known as normalized cut and how it is applied to image segmentation. The numerical complexity of the process makes its computational implementation very expensive in terms of time and memory. This procedure requires finding the subdominant eigenvector of a real dense symmetric semi definite positive matrix of great dimensions called Laplacian. Through some modifications of the normalized cut method, we obtained a special kind of segmentation known as edge detection. For this type of segmentation, the Laplacian has a pentadiagonal structure, which results in a remarkable save of computational resources. Another characteristic of this method is that the power method converges very fast. A deeper study of this behavior led us to obtain a closed form to perform edge detection that is even cheaper. We present our results and a comparison with other edge detection techniques. Also, we show an application of this method to motion detection in a video stream.

## 6 Minisymposia-Oil, Weather and Geo-science Modeling

### 6.1 Adaptive Wavelet Discretization of PDEs on the Sphere: a Framework for Geophysical Flow

Thomas Dubos<sup>1</sup>, Nicholas Kevlahan<sup>2</sup>, Mani Mehra<sup>3</sup>

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<sup>3</sup>Department of Mathematics, IIT Delhi, India

We present a dynamically adaptive numerical method for solving partial differential equations on the sphere. This approach provides an alternative to adaptive mesh refinement (AMR) methods for static and dynamic grid refinement. The method is based on second generation spherical wavelets on a multiscale hierarchy of structured icosahedral/hexagonal grids. The Laplace-Beltrami, Jacobian and flux-divergence operators are approximated at each level of resolution using standard finite volume discretizations. Wavelet decomposition is used for grid adaptation, error control and interpolation/coarse graining between the adapted grids of successive resolutions. The accuracy and efficiency of the method is demonstrated by applying it to the advection equation, diffusion equation and the Poisson problem on the sphere.

It is straightforward to apply this method to solve the shallow water equations on the sphere. However, in order to retain the discrete conservation properties of mass- and potential vorticity conserving schemes, some additional modifications to the multiscale operators are required. In particular, we will discuss extensions to formally conservative discretizations on both collocated (Z) and staggered (C) grids.

Finally, we will highlight the similarities and difference of the wavelet approach compared to AMR.

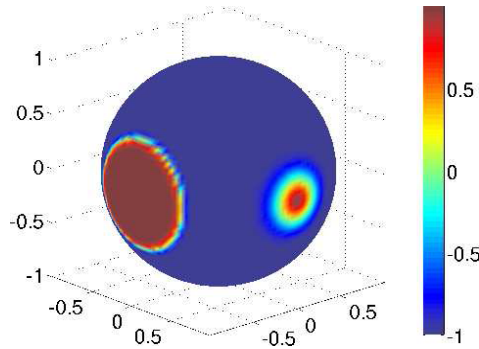


Figure 2.1: Test function: circular front and bell-shape.



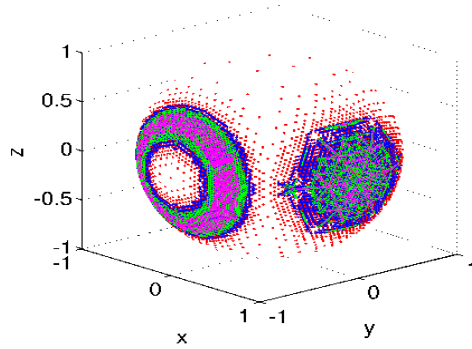


Figure 2.2: Adapted grid with 8 levels of dyadic refinement achieving a relative error of  $10^{-5}$ .

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## 6.2 3D Parallel Elastodynamic Modeling of the Wave Propagation of Earthquakes: Supercomputer Implementation and Urban and Industrial Applications

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Realistic 3D modeling of the wave propagation of large magnitude earthquakes through hundreds of kilometers of the earth's crust poses both a numerical and a computational challenge. The 3D finite difference modeling (3DFD), which is highly suitable for parallel execution on today's distributed memory parallel supercomputers has proved very successful to this end. Herewith, the mathematical and computational aspects of an ongoing project on the 3DFD modeling of the wave propagation of earthquakes, implemented recently on an optimized seismic wave propagation parallel finite difference code (3DWFPD) will be presented. Results of its application to obtain 3D synthetic seismograms for the 2008 Wenchuan, China, Mw 7.9 and for Mw 8.5 scenario earthquakes in Mexico will be shown. Finally, the results obtained with this type of modeling to estimate the seismic hazard and provide seismic recommendations at two industrial sites will be presented.

### 6.3 Dispersion from Flares in a Cross-Wind

**Bruce R. Sutherland<sup>1</sup>, Joseph K. Ansong, Alex Anderson-Frey**

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Sour gas flares attempt to burn off hydrogen sulfide (H<sub>2</sub>S), a poisonous gas that can kill at concentrations higher than 100PPM. Because in some areas of the Rocky Mountain foothills the concentration of the gas before burning can be as high as 20%, flaring must be extremely efficient to prevent disaster. Recent studies have shown that cross-winds can reduce the efficiency to 30% meaning the concentration of unburned gas at the source can be as high as 60000PPM. Engineers rely on atmospheric dispersion to reduce the concentration to tolerable levels before the plume extends to the ground. To predict the dispersion of the gas close to the source, the US Environmental Protection Agency uses a numerical model, AERMOD, that heuristically adapts plume theory to account for the effects of winds and atmospheric inversions. They do not account for the fact that H<sub>2</sub>S is heavier than air at room temperature and so would tend to pool in valleys after cooling. We have performed laboratory experiments to examine the dynamics of positively and negatively buoyant plumes in uniform and stratified environments with a uniform background flow. The results are then compared with the predictions of the AERMOD model.

### 6.4 Development of High Performance Numerical Schemes and Tools for High-End Earth Science Applications

**Tony Drummond**

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The challenging road ahead for the development of software in high-end computing is epitomized by the urgency in identifying and making available robust software technologies that will rapidly enable the development of more complex software codes. The US DOE Advanced Computational Software (ACTS) Collection is a set of advanced and portable tools that can be used in the development of high performance simulation codes. A good number of the tools in the ACTS Collection provide numerical functionality that includes robust implementations of algorithms for the solution of linear and nonlinear systems of equations, eigenvalue problems, non-linear optimization problems and ordinary differential equations. Earth Science applications have the tendency to demand large amounts of computational resources, and this demand increases exponentially as the complexity of the phenomena being study is also increased. Notable examples of such applications are found in climate, atmospheric, and ocean modeling, as well as simulations of geochemical, hydrological and hydrobiological processes. Our work consist on providing solutions to fast track the development of these high-end applications through reuse of robust and scalable software tools. Here we describe some key developments in

the ACTS Collection to provide a solution to support sustainable high performance software. We illustrate a few examples of the use of this technology to address some common problems in Earth Science Application. We present a software infrastructure for the integration of complex numerical schemes like the one used to couple large scale multi-domain and multi-resolution models. The technologies presented here are designed platform independent and geared towards the petascale and beyond computing.

## **6.5 On Modeling Subdiffusion and the problem of deconvolution in well test analysis**

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The diffusion equation in radial geometry is the classical single-phase flow model in the surroundings of an oil well. We briefly review this model and introduce the subdiffusion property in pressure transient tests observed on some oil fields. Some generalizations of the conventional model have been introduced for better descriptions of this property. Noteworthy are models with non-Darcy flow or fractional  $t$ -derivatives. We revisit these models from a theoretical perspective. An important application of pressure transient tests is to estimate phenomenological parameters at the interwell length scale from pressure data collected in the field. Arguably, the main step in this identification is a problem of deconvolution. Consequently, we introduce a numerical method for deconvolution together with some analysis.

## **6.6 Numerical PDE Solvers for Exploration Seismology**

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The discovery and production of economic reserves of oil and gas resources depends on accurate imaging of the earth's subsurface accomplished through active seismic methodologies. A key step in the imaging algorithm is forward modeling of seismic wave propagation through the viscoelastic medium of the earth.

We discuss the mathematical models for seismic wave propagation and a variety of numerical methods used in practical algorithms for simulating the PDEs involved. Our emphasis is on Gabor methods which provide a localized Fourier-type algorithm for effectively solving the numerical models. A comparison with finite difference and Galerkin methods will be presented.

This is joint work with Dr. G. Margrave, in the POTSI project of the MITACS NCE.

## 6.7 The General Curvilinear Environmental Model

**Jose Castillo**

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The General Curvilinear Environmental Model is a high-resolution system composed of the General Curvilinear Coastal Ocean Model (GCCOM) and the General Curvilinear Atmospheric Model (GCAM). Both modules are capable of reading a general curvilinear grid, orthogonal as well as non-orthogonal in all three directions.

These two modules are weakly coupled using the distributed coupling toolkit (DCT). The model can also be nested within larger models and users are able to interact with the model and run it using a web based computational environment.

The GCEM Computational Environment (GCEM-CE) allows the model to be hosted as a Web service for a variety of clients (human or application) to run simulations across the heterogeneous computing environments provided by a cyber infrastructure (such as those on the NSF TeraGrid). The GCEM-CE uses the SDSU Cyber infrastructure Web Application Framework (Cyber Web) to provide middle-ware and back-end services. Cyber Web improves on standard grid-enabled toolkits and functions (e.g. job execution, account management, task history, GSI authentication, etc) by hosting its applications as a collection of Web services, portal Web pages, or even Web 2.0 Social networking gadgets).

Some test cases will be presented to demonstrate the capabilities of our system as well as to highlight the main differences with currently used systems.

## 6.8 Characterization of Fractured Oil Reservoirs with Global Optimization

**Susana Gómez**

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To be able to predict the reservoir behavior, including the production of oil, it is necessary to find the properties of the porous media. This can be achieved using well test data, solving an inverse ill posed problem.

In this work a recently developed Triple Porosity Model will be used to get the pressure in the matrix, fractures and vugulus. The solution of the differential equations, is obtained using Laplace transform and needs an inverse ill posed method to obtain the pressure in real time. It also needs acceleration techniques to obtain in reasonable time, the solution for partially penetrated wells.

The resulting optimization problem formulated to fit the well test data, resulted in a highly ill-conditioned problem if solved in real time. We propose here the solution in Laplace time.

In this work we will discuss these features and the methodology used. Numerical results comparing alternative local and global optimization methods will be presented for an exhaustive set of synthetic data.

## **6.9 The Three-Dimensionalization of Barotropic Instability**

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The ocean contains a variety of motions over a vast range of length and time scales. The general circulation of the ocean is predominantly forced at the surface on synoptic length-scales, whereas the dissipation due to molecular viscosity is on length scales less than a centimeter. The mechanisms through which the ocean cascades energy have been intensely studied and at present the component of the oceanic energy budget that is least understood is the transfer of energy from the mesoscale to the submesoscale. The generation of a submesoscale energy cascade can arise due to unbalanced motions, one important example of which is the instability of shear flows. Molemaker, McWilliams and Yavneh (2005) have studied the downscale cascade induced by baroclinic instability in a primitive equation model. It is found that by accurately resolving the small scale processes, the downscale cascade can be enhanced.

In this work we begin a similar study but in the context of barotropic instability. Poulin and Flierl (2003) studied the instability of a barotropic Bickley jet in the context of the Shallow Water Model. They found that with order one Rossby numbers and large free-surface displacements, there can be a strong asymmetry between cyclones and anticyclones. Perret et al. (2006) found asymmetries in the frontal regime with order one Rossby numbers. The aim of this study are as follows: 1) Investigate the barotropic instability with order one Rossby and Burger numbers with relatively weak stratification. 2) Determine the effect of increasing vertical resolution has on resolving the 3D instability, both in the early onset and after the nonlinear adjustment. 3) We compare the effect of the Non-Traditional (NT) Coriolis parameters versus making the Traditional Approximation (TA). This is because the NT terms can transfer momentum between the zonal and vertical directions thereby inducing vertical velocities.

## **6.10 Sensitivity Analysis in Climate. The Ensemble Bred Vector**

**Juan M. Restrepo**

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Several weather centers around the world are actively using or planning to use Bred Vectors, Singular Vectors, and/or Lyapunov Vectors to infer the (forward) sensitivity of model outcomes in weather and in climate. They are also said to be useful in characterizing the degree of uncertainty in model predictions. Several proposals have been put forth to use these vectors for a reduced representation of the background error in data assimilation calculations.

I will describe how bred vectors compare to Lyapunov vectors in two dynamic nonlinear evolution problems, and use these to highlight crucial mathematical properties, which are important to keep in mind when considering using them to make qualitative sensitivity predictions. I will report on joint work with Nusret Balci (IMA), Anna Mazzucato (PSU), and George Sell (U Minn), in which we refine the definition of the Bred Vector to encompass ensembles of predictions and compare its robust features to those of the more traditional bred vectors.

## 7 Minisymposia-Biomathematics

### 7.1 Multiple Waves for the Same Pandemic: Local Transportation and Social Distancing Explain the Dynamics of the A-H1N1 Epidemic During 2009 in México

**Marco Arieli Herrera-Valdez, Maytee Cruz-Aponte and Carlos Castillo-Chavez**

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Influenza outbreaks have been of relatively limited historical interest in México. The 2009 influenza pandemic not only changed México's health priorities but also brought to the forefront some of the strengths and weaknesses of México's surveillance and public health system. A year later, México's data show an epidemic pattern characterized by three waves. The reasons this three-wave patterns are theoretically investigated via models that incorporate México's general trends of land transportation, public health measures, and the regular opening and closing of schools during 2009. The role of vaccination is also studied taking into account delays in access and limitations in the total and daily numbers of vaccines available. The research in this article supports the view that the three epidemic waves are the result of the synergistic interactions of three factors: regional movement patterns of Mexicans, the impact and effectiveness of dramatic social distancing measures imposed during the first outbreak, and the summer release of school children followed by their subsequent return to classes in the fall. The three waves (outbreaks) cannot explained by the transportation patterns alone but only through the combination of transport patterns and changes in contact rates due to the use of explicit or scheduled social distancing measures. The research identifies possibly vaccination schemes that account for the school calendar and whose effectiveness are enhanced by social distancing measures. The limited impact of the late arrival of the vaccine is also analyzed.

### 7.2 Stochastic Modeling of HIV Infection in Treated Patients

**Daniel Coombs**

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I will present continuous time branching processes designed to model aspects of HIV-virus and T-cell dynamics in treated patients. During successful antiretroviral therapy, the viral load measured in the blood of an infected patient drops to very low levels, and is undetectable by routine tests. However, infection persists and occasionally, there are short periods of detectable viral load. We use modelling to examine the hypothesis that very low viral loads during treatment can be explained principally by the activation of cells latently infected by HIV before the initiation

of treatment, and that viral blips then represent large deviations from the average. I will also present results pertaining to post-exposure prophylaxis (PEP) with antiretroviral drugs designed to eradicate HIV infection immediately after exposure for example among health care workers. We use simulation methods and novel numerical methods to accurately calculate probability distribution functions for virus and cell concentrations in the blood. This is joint work with Jessica Conway.

### 7.3 Mechanisms of Resistance in Populations Dynamics

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The delivery of a growth inhibitor into an environment has the effect of killing most, if not all, of the resident susceptible microbial strains, leaving room for any resistant survivors to propagate and takeover. This is one of the most common problems in medicine (where the inhibitor is, in fact, an antibiotic), agriculture (with pesticides) and, in general, in all of those scenarios that involve the use of biocides or growth inhibitors.

Competition between species in the presence of an inhibitor has been studied by Lenski and Hattingh, Hsu and Waltman, etc. Nevertheless, in their models, these authors consider mainly two independent organisms. In this work I present some models that describe competition between two or more organisms for the same nutrient, in the presence of an inhibitor or antibiotic where the main consideration is the presence of a wild organism and the other organisms are consequence of the resistance mechanisms that the presence of the antibiotic generates on the wild strain.

### 7.4 A Model of Thyroid Cancer Initiation and Growth in Autoimmune Thyroiditis

**Stephen J. Merrill**  
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In the most common cause of hypothyroidism, low thyroid hormone (T4) results in high levels of the controlling hormone TSH. This hormone acts to both encourage thyroid nodule development and drive growth. In this talk, using a deterministic model of the production of the T4 and TSH in the presence of autoimmune thyroiditis (Hashimoto's disease), a stochastic model of the initiation and the growth of follicular cancer in the thyroid is developed. The question here is to examine the difference in the development of this cancer and growth with and without treatment of the underlying hypothyroidism.



## **7.5 Quantitative Analysis of Single Particle Tracking Experiments: Applying Ecological Methods in Cell Biology**

**Gerda De Vries**

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A commonly used experimental technique to study the movement of biomolecules in the cell membrane is Single Particle Tracking (SPT). SPT involves tagging biomolecules with a fluorescent label and observing and recording their trajectories over time. A diffusion coefficient then can be extracted from the data from mean square displacement calculations. Although the diffusion coefficient provides an overall measure of mobility, it does not provide insight into the underlying heterogeneity of the membrane environment.

Since the method of data collection from individual biomolecules is analogous to that from individual animals, we propose to use methods from ecology to provide spatial insight. Ecologists regularly quantify animal movement using the concepts of correlated random walk, net squared displacement, and first-passage time. In this talk, we will demonstrate the applicability of these methods in the context of cell biology. In particular, we will show how we can distinguish biomolecule trajectories undergoing a correlated random walk from those that do not, and how we can identify the presence of transient confinement zones in molecular diffusion.

Acknowledgements: This is joint work with Vishal Rajani (Department of Mathematical & Statistical Sciences, University of Alberta), Gustavo Carrero (Centre for Science, Athabasca University), and Christopher W. Cairo (Department of Chemistry, University of Alberta).

## **7.6 Interaction Between Meandering Spiral Waves and Circular Shape Obstacles: a Numerical Study**

**Daniel Olmos Liceaga**

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Ventricular fibrillation is a very important health problem as is the cause of most of the sudden deaths in North America. Waves of electrical activity are sent by the SA node, propagate through the cardiac tissue and activate the mechanisms of cell contraction, and therefore are responsible to pump blood to the body harmonically. A spiral wave is an abnormal auto sustainable wave that is responsible of certain types of arrhythmias. When these waves break up, give rise to the fibrillation regime, in which there is a complete loss in the coordination of the contraction of the heart muscle. Interaction of spiral waves and obstacles is also of great importance as it is believed that the attachment of a spiral wave to an obstacle can provide with a transition of two different arrhythmias. An obstacle can be a vein or ischemic tissue

originated from a previous infarct. In this talk, we present a numerical study of the interaction of meandering spiral waves and circular obstacles and provide with conditions under which the probability of attachment increases.

## 7.7 Animal Gaits and Symmetries of Periodic Solutions

**Martin Golubitsky**

Ohio State University, USA

This talk will have two parts. First, I will briefly describe previous work on gaits of four-legged animals (based on distinguishing gaits, such as walk, trot, and pace, by their spatio-temporal symmetries). Second, I will discuss how the application to gaits has led to results about phase-shift synchrony in periodic solutions of coupled systems of differential equations.

## 7.8 Numerical Solution of the Chemical Master Equation: mRNA Bursting in a Gene Network with Negative Feedback Regulation

**Moisés Santillán**

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We introduce in this work a couple of algorithms to compute the stationary probability distribution for the chemical master equation of arbitrary chemical networks. We employ these algorithms to study the mRNA and protein probability distributions in a gene regulatory network subject to negative feedback regulation. In particular, we analyze the influence of the promoter activation/deactivation speed on the shape of such distributions. We find that a reduction of the promoter activation/deactivation speed modifies the shape of those distributions in a way consistent with the phenomenon known as mRNA (or transcription) bursting.

## 7.9 Objective Dosing Regimens Based on an Integrative PK/PD Formalism

**Fahima Nekka<sup>1,2,3</sup> and Jun Li<sup>1,2</sup>**

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To enhance the drug efficacy and avoid non necessary toxicity, a good choice of dosing regimens is crucial. However, the general approach, mainly relying on health givers personal experience or clinical evidences, often lacks quantitative and objective criteria.

In this work, based on mechanistic considerations of drug effect, we introduce new criteria to be used for pharmacological decisions. This approach builds up on a previously developed pharmacokinetic/pharmacodynamic (PK/PD) formalism. Two typical antibiotic agents, one being concentration-dependent and the other time-dependent are used to illustrate our idea. As application, various dosing regimens are discussed and compared within the classical framework of compartmental models.

Echoing the non additivity of the pharmacological effect in terms of dose, this rational-based criterion quantitatively delineates different dosing regimens by draining, as large as possible, the information from up-to-date pharmacological knowledge. Given a target efficacy, the dosing regimen can be clearly identified at the patient's convenience.

Our work suggests the need for the establishment of more objective standards for protocol design in drug R&D and clinical practice.

### **7.10 Growth Rate and Shape as Possible Control Mechanisms for the Selection of Mode Development in Optimal Biological Branching Processes: the Patterning Program in Lung Formation**

**Tomas Alarcon<sup>1</sup>, Miguel Angel Herrero<sup>2</sup>, Pablo Padilla<sup>3</sup>**

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Recently three branching modes were characterized during the formation of the lung in mice. Experimental data show that these modes are highly stereotyped and correspond to domain formation, planar bifurcation and three dimensional branching respectively. At the same time it is proved that although genetic control mechanisms are presumably related to the selection of any of these modes, other external factors will most probably be involved in the branching process during development. In this paper we propose that the underlying controlling factors might be related to the rate at which the tubes that form the lung network grow. We present a mathematical model that allows us to formulate specific experimental predictions on these growth rates. Moreover we show that according this formulation, there is an optimization criterion which governs the branching process during lung development, namely, efficient local space filling properties of the network. The basic idea is that if there is no space limitation the branches are allowed to grow freely and faster, selecting one branching mode, namely, domain formation. As soon as volume constraints appear the growth rate decreases, triggering the selection of planar bifurcation. Finally, if space is further limited, orthogonal bifurcation is selected. We present a rigorous mathematical explanation of this phenomenon as well as asymptotic justifications and numerical simulations.

## 8 Minisymposia-Financial Mathematics and Economy

### 8.1 The Exchange of Derivatives. An Analysis with a Functional of Cumulative Prospect Theory

**Erick Treviño-Aguilar**

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We study the point of view “derivatives as source of revenues”. The initial situation starts when a firm sells a derivative with payoff  $H$ . The firm controls risks and generates gains by taking a long position in an optimally selected financial instrument  $H^*$  valued in an underlying financial market. In this sense we study a problem of optimal exchange. The firm faces scenarios of losses and scenarios of gains. The scenarios of risk of a position  $V$  determine the event  $\{H > V\}$ . The scenarios of gains generates the event  $\{H < V\}$ . We propose to quantify the risk of the shortfall  $(H - V)^+$  and the utility of the gain  $(V - H)^+$ . To this end, we use a functional involving concave probability distortions motivated by the cumulative prospect theory of Kahneman and Tversky. We prove the existence of an optimal exchange. The trade-off between gains and losses is strongly reflected in the structure. There is a region of “going for revenues”, where the firm generates gains and a region of “strict hedging” where the generated capital falls short of the obligation  $H$ . Moreover, we are going to see that the optimal exchange is achieved by dynamically trading in the underlying market. In the last part of the paper we prove an intuitive “separating principle”, if the market is complete: The initial capital is optimally separated into two funds, one fund controls risk and the other one generates utility.

Keyword: Capacities, Cumulative Prospect Theory, Derivatives, Efficient Hedging, Exchange.

### 8.2 Credit Risk in the Private World

**Luis Seco**

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Credit risk usually focuses on public entities, whether it is publicly traded companies or sovereigns. In this talk, I will provide an overview on how credit risk frameworks can be used to model default risk and asset returns for private and fund investments. The talk will include both structural as well as reduced form models, and will be expository in nature.

### **8.3 Optimal Investment With Performance Fees**

**Gerard Brunick**

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In this talk we will consider the problem of optimal asset allocation for an agent who may invest in a money market fund, a stock, and a hedge fund. We model the risky assets as correlated geometric Brownian motions, and we assume a power investor who maximizes discounted utility from consumption on an infinite horizon. We further suppose that the investment in the hedge fund is subject to performance fees which are determined by a high water mark relative to a hurdle rate. We will see that, in this setting, the problem amounts to the optimal control of a reflected diffusion. We will examine the associated Hamilton-Jacobi-Bellman equation and show the existence of an optimal control.

### **8.4 Calibration of Vasicek and CIR Models Via a Generating Function Approach**

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We propose a new method to calibrate the Vasicek and CIR models to observed market data. A generating function is introduced and recursive formulas involving the market data and the derivatives of this generating function are developed. The model parameters are found by solving a system of linearly independent equations arising from the recursive formulas. We include a numerical illustration by first generating bond prices using the exact bond price solution for each of the Vasicek and CIR models. Then the proposed technique is tested on these generated bond prices. For the CIR model the polylogarithm function is employed to fully evaluate the derivative of the generating function.

This is joint work with Rogemar S. Mamon, University of Western Ontario.

### **8.5 A Novel Approximation to Loss Probabilities of Credit Portfolios**

**Meng Han<sup>1</sup>, Kenneth R. Jackson, Alexander Y. Kreinin**

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Credit risk analysis and management at the portfolio level is a challenging issue for financial institutions due to their portfolios' large size, heterogeneity and complex correlation structure. The conditional independent framework is widely used to calculate loss probabilities of credit portfolios. From the perspective of computing, the existing approaches fall into two categories: the simulation-based approximation and the asymptotic approximation. However, the simulation-based

approximation involves a two-level Monte Carlo simulation, which is extremely time-consuming, while the asymptotic approximation, which is rooted from the Law of Large Number (LLN), is not accurate enough for tail probabilities, especially in the case of heterogeneous portfolios. In the present work, we give a more accurate asymptotic approximation based on the Central Limit Theorem (CLT), and gives generous conditions under which the CLT approximation can be applied. To further increase accuracy, we also propose a hybrid approximation, which combines the simulation-based approximation and the asymptotic approximation. We test our approximations with some hypothetical and real portfolios. Numerical examples show that the at the cost of comparable computing time, the CLT approximation is more accurate than the LLN approximation for both homogenous and heterogeneous portfolios, while the hybrid approximation is even more accurate than the CLT approximation, and it significantly reduces the computing time comparing with the simulation-based approximation.

## 8.6 A Cournot-Stackelberg Model of Supply Contracts With Financial Hedging

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We study the performance of a stylized supply chain where multiple retailers and a single producer compete in a Cournot-Stackelberg game. At time  $t = 0$  the retailers order a single product from the producer and upon delivery at time  $T > 0$ , they sell it in the retail market at a stochastic clearance price. We assume the retailers' profits depend in part on the realized path of some tradeable stochastic process such as a foreign exchange rate, interest rate or more generally, some tradeable economic index. Because production and delivery do not take place until time  $T$ , the producer offers a menu of wholesale prices to the retailer, one for each realization of the process up to some time  $\tau$ , where  $0 \leq \tau \leq T$ . The retailers' ordering quantities therefore depend on the realization of the process until time  $\tau$ . We also assume, however, that the retailers are budget-constrained and are therefore limited in the number of units they may purchase from the producer. The supply chain might therefore be more profitable if the retailers were able to reallocate their budgets across different states of nature. In order to affect a (partial) reallocation, we assume that the retailers are also able to trade dynamically in the financial market. After solving for the Nash equilibrium we address such questions as: (i) whether or not the players would be better off if the retailers merged and (ii) whether or not the players are better off when the retailers have access to the financial markets. Our model can easily handle variations where, for example, the retailers are located in a different currency area to the producer or where the retailers must pay the producer before their budgets are available. Finally, we consider the case where the producer can choose the optimal timing,  $\tau$ , of the contract and we formulate this

as an optimal stopping problem.

## **8.7 An LP Model to Settle Transactions in the Mexican Securities Market**

**Alejandro De los Santos**

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The restrictions that are applied to reduce risks in the securities market impose a set of constraints that should all be taken into account jointly, while deciding which buy-sell transactions can be settled. Doing this without a mathematical model is inefficient. At the same time, solving the model with sophisticated methods may take more time than what the market is willing to wait.

The Mexican Central Bank designed an LP model that tackles this problem and proposed a methodology that, even though, it uses a suboptimal solution, this solution is obtained sufficiently fast to be useful for the market participants. Indeval, the institution responsible for the custody of all the securities that are traded in Mexico, as well as for the final settlement of all transactions in the market, builds and solves this model every day, every few minutes. For the full implementation of the system and the benefits it represents on the efficiency of the market, Indeval received from INFORMS the 2010 Franz Edelman award.

During the presentation, the problem will be presented and a simplified version of the LP model will be constructed. We will also take a brief detour to picture how securities are bought and sold in the Mexican market.

## 8.8 On the Pensioner's Management Problem: a Time Consistent Approach

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We consider a more general form of the Merton problem. The stock is as usual driven by

$$dS(t) = S(t) [\alpha dt + \sigma dW(t)], 0 \leq t \leq \infty,$$

where  $\{W(t)\}_{t \in (0, \infty)}$  is a 1-dimensional Brownian motion on a filtered probability space  $(\Omega, \{\mathcal{F}_T\}_{0 \leq T \leq \infty}, \mathcal{F}, \mathbb{P})$ .

A decision-maker in this market is continuously investing his/her wealth in the stock/bond, is consuming and is buying life insurance. Moreover he/she is receiving income at the continuous deterministic rate  $i(t)$  at each point in time  $t$ .

An investment-consumption-insurance strategy is determined by the amount he/she invests in the bond/stock  $\zeta(t)$  at time  $t$ , the consumption rate  $c(t)$  and the insurance rate  $p(t)$ . Given a strategy process  $\{\zeta(t), c(t), p(t)\}_{t \in [0, \infty]}$ , the equation describing the dynamics of wealth  $X^{\zeta, c, p}(t)$  is given by

$$dX^{\zeta, c, p}(t) = rX^{\zeta, c, p}(t)dt - c(t)dt - p(t)dt + i(t)dt + \zeta(t)(\alpha dt + \sigma dW(t))$$

The above equation is usually referred to as the self-financing condition. The initial wealth  $X^{\zeta, c, p}(0) = X(0) \in (0, \infty)$ , is exogenously specified.

The time horizon is fixed (e.g.  $T=65$  years) and the death rate at time  $t$  is  $\lambda(t)$ .

If the decision-maker dies at time  $t, 0 < t \leq T$ , then his/her family will get the insurance amount  $l(t)p(t)$ . Thus decision-maker legacy when he/she dies at time  $t$  is wealth plus insurance amount, i.e.,

$$Z(t) = \eta(t)X(t) + l(t)p(t) \quad (2.1)$$

Although the insurance premium  $p(t)$  is allowed to be negative we require that the legacy  $Z(t)$  stays positive.

At all times the decision-maker has the same von Neuman-Morgenstern power utility  $U(x) = U_\gamma(x) = \frac{x^\gamma}{\gamma}$ , for intertemporal consumption and  $\bar{U}(X) = nU_\gamma(x)$  for final wealth.

When it comes to his/her legacy we assume that the family has the same von Neuman-Morgenstern power utility  $U(x) = U_\gamma(x)$ , but when measure it the decision-maker weights by a deterministic time varying Pareto weight  $m(t)$ .



In order to evaluate the performance of an investment-consumption-insurance strategy the decision maker uses an expected utility criterion; for an admissible strategy process (and under certain technical assumptions)  $\{\zeta(s), c(s), p(s)\}_{s \in [0, \infty]}$  and its corresponding wealth process  $\{X^{\gamma, c, p}(s)\}_{s \in [0, \infty]}$  (see (0.1)) we denote the expected utility functional by

$$J(t, x, \zeta, c, p) \triangleq \mathbb{E} \left[ \int_t^{T \wedge \tau} h(s-t) U_{\gamma}(c(s)) ds + nh(T-t) U_{\gamma}(X^{\zeta, c, p}(T)) 1_{\{\tau > T | \tau > t\}} \right. \\ \left. + m(\tau-t) \hat{h}(\tau-t) U_{\gamma}(X^{\zeta, c, p}(\tau)) 1_{\{\tau \leq T | \tau > t\}} \right] | X^{\zeta, c, p}(t) = x, \quad (2.2)$$

where  $h, \hat{h}$  are discount functions.

We allow the insurance premium rate  $p(t)$  to be negative which means that the decision maker can sell life insurance. The value function  $v(t, x)$  is the maximum over all admissible strategies  $(\zeta, c, p)$  of  $J(t, x, \zeta, c, p)$ .

This gives rise to a HJB whose coefficients are time-dependent and therefore giving rise to time-inconsistency. We then introduce the notion of equilibrium.

More precisely,  $(\bar{\zeta}, \bar{c}, \bar{p})$  is an equilibrium policy iff  $\forall t \in [0, T]$  and  $\epsilon > 0$  sm

$$\liminf_{\epsilon \downarrow 0} \frac{J(t, x, \bar{\zeta}, \bar{c}, \bar{p}) - J(t, x, \zeta_{\epsilon}, c_{\epsilon}, p_{\epsilon})}{\epsilon} \geq 0, \quad (2.3)$$

where  $(\zeta_{\epsilon}, c_{\epsilon}, p_{\epsilon})_{s \in [t, T]}$  is a strategy coinciding with  $(\bar{\zeta}, \bar{c}, \bar{p})$  on  $[t+\epsilon, T]$  and arbitrary on  $[t, t+\epsilon]$ .

We show that we can give an explicit solution in the case of power utilities.

## 8.9 Crisis! Investment and Consumption in Market Models with Stochastic Volatility, Jumps and Contagion

**Tom Hurd**

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Recent crises in the global markets have demonstrated yet again that even well-diversified portfolios are severely tested in times of crisis. Our aim in this talk is to investigate how a rational investor might try to anticipate such crisis scenarios, and to compute how optimal strategies must be adjusted in light of their potential impact. We begin looking at a number of distinct modeling approaches that incorporate market crises, and discuss their relative merits. It turns out that the optimization problems one faces are superficially rather similar in structure in these different models. Nonetheless there are certain mathematical hurdles to overcome before a general result can be stated. Towards the end of the talk, we will get a flavor of the type of optimal strategies that result, and see certain effects they incorporate.

## 8.10 Portfolio Turnpike in Incomplete Markets

**Paolo Guasoni, Kostas Kardaras, Scott Robertson, Hao Xing**

Portfolio turnpike is an intuitive property of the portfolio choice problem. It states that if preferences of two agents are similar toward large wealth, then in a market which grows indefinitely, the optimal investment strategies of these two agents are similar as horizon increases. As a result, the agent's long-run optimal strategy only depends her preference toward large wealth. This problem dates back to 1958 and it has been proven in different market settings. But all results assume the completeness of the market. In this talk, we will discuss whether this property holds in incomplete markets. We show that when the investment strategy of one agent is myopic, the turnpike property holds in a general incomplete market with semimartingale dynamics. When the optimal strategy is not myopic, we study a market model whose asset prices are driven by a common factor. We show that the turnpike holds in this market, if the factor process is positive ergodic in a long-run measure.

## 8.11 Optimal Utilization of Variable Annuity Guarantees

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Variable Annuities contain numerous living and death benefits which have attracted recent attention within the literature on finance and insurance. One of the established and stylized facts in this research is that many widely available products sold in the U.S. were underpriced, likely because the insurance company wasn't hedging properly and/or using actuarial (as opposed to financial) techniques for pricing. Indeed, the popularity as well as the liability created by these products were partially responsible for the financial difficulties experienced by numerous insurance companies during the 2008/2009 crisis. This pricing and hedging literature continues to grow.

A question which has attracted less scholarly and research attention but is equally important, is how exactly consumers who hold these guaranteed should best manage them. In the U.S. market alone there are over \$1 trillion worth of these guarantees held by individual investors, so this is a question financial advisors are increasingly being faced with. The optimal policy for a consumer seeking to maximize lifetime utility with these products 'in an incomplete market' isn't necessarily a policy that induces the maximum liability to the issuer. In other words, the hedging strategy (for the issuer) isn't the symmetric opposite of the dynamic utilization strategy (for the buyer). I will discuss some results in this direction, obtained with Huaxiong Huang and Moshe Milevsky.

## 8.12 Unified Multi-Name Credit-Equity Modeling: a Multivariate Time Change Approach

**Rafael Mendoza-Arriaga**<sup>2</sup>

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We develop a new class of multi-name unified credit-equity models that jointly model the stock prices of multiple firms, as well as their default events, by a multi-dimensional Markov semimartingale constructed by multivariate subordination of jump-to-default extended constant elasticity of variance (JDCEV) diffusions. Each of the stock prices experiences state-dependent jumps with the leverage effect (arrival rates of large jumps increase as the stock price falls), including the possibility of a jump to zero (jump to default). Some of the jumps are idiosyncratic to each firm, while some are either common to all firms (systematic), or common to a subgroup of firms. For the two-firm case, we obtain analytical solutions for credit derivatives and equity derivatives, such as basket options, in terms of eigenfunction expansions associated with the relevant subordinated semigroups.

## 8.13 On Pricing and Hedging Problems of Relevance to Liquid Reinsurance Markets and Insurance Securities

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This paper discusses the problem of pricing and hedging insurance securities in incomplete markets. A model for an insurance loss process, originated in reinsurance theory, is brought to the insurance securitization framework. The range of contingent claims prices consistent with arbitrage considerations is studied and a method of constructing pricing bounds, based on extremal convex distributions, is proposed. Hedging strategies based on local and global risk criteria are then discussed, showing how optimal hedging beyond the usual risk minimization criteria can be approached numerically.

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<sup>2</sup>Joint work with: Vadim Linetsky, Northwestern University

## 9 General Session - 1

### 9.1 Extensional Flow of a Viscoelastic Thread

**David O. Olagunju**

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A one-dimensional model for the extensional flow of a viscoelastic thread will be discussed. The model describes the deformation of a filament attached two coaxial plates and stretched at an exponential rate. Computations showing the effect of capillary instabilities and the strain-hardening on the thinning and eventual rupture of the thread will be presented for a number of constitutive models including Oldroyd-B, Giesekus and FENE models.

### 9.2 Fluid Flow and Tracer Transport Simulation in Oil Reservoirs using a Direct Streamline Approach

**Manuel Coronado<sup>1</sup>, Jetzabeth Ramírez-Sabag<sup>1</sup>, Oscar Valdiviezo-Mijangos<sup>1</sup>, Joaquín López-López<sup>2</sup>**

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A simple numerical code has been developed to describe the steady-state fluid flow pattern and the advective-dispersive transport of a tracer pulse in reservoirs by employing a direct stream-line approach. The purpose of this simulator is to provide practitioners with a simple tool to analyze tracer tests in multi-well reservoirs without needing to run expensive commercial codes that are certainly more precise, but demand high amount of geological and fluid information as well as large computer resources. By this mean the gap between these large complex simulators and the standard two-well analytical models is therefore been fulfilled. Within this context an incompressible fluid moving in a horizontal uniform porous media layer is assumed. A tracer pulse is introduced in this reservoir layer through an injection well and its arrival at the surrounding production wells in the same layer is observed. The tracer breakthrough curves provide information on the preferential reservoir communication channels and on the porous media properties. By considering fluid flow conservation an expression for the fluid velocity of any single well is calculated, and the total fluid flow pattern is evaluated by means of a superposition principle. Once the velocity field is known, the concentration of the multiple pieces of the tracer pulse are followed along stream lines until the lines reach a production well or leave the working area. Longitudinal tracer dispersion along the stream line is taken into account, and the dispersion coefficient is assumed proportional to the tracer speed, as it is empirically known. The final tracer breakthrough curve at a given production well is formed by the superposition of all tracer pulse pieces arriving at that well. The amount of model parameters is two for isotropic formations and four

for anisotropic cases. A numerical code in Matlab has been written, which has been registered under the name Flow and Transport simulator (F+Tr). It provides colored graphic outputs for the total streamline pattern and the final tracer breakthrough composition at each production well. The simulator has been applied to fit synthetic and field tracer test data.

### **9.3 Regulatory Networks, Chemical Oscillations, Biological Switches, and Intrinsic Noise in Cells. Why and What for?**

**Eduardo S. Zeron**

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The cellular communications that regulates cell fate must be precisely controlled to avoid dangerous errors. How is this achieved? Recent work has highlighted the importance of positive and negative feedback networks in the dynamic regulation of signalling. These feedback interactions can impart precision, robustness, noise rejection and versatility to cellular signals. They can also produce interesting emergent dynamical properties like biological switches and chemical oscillators, whose properties and purpose must be explained.

### **9.4 Smooth Global Solutions to the Eikonal Equation**

**Jaime Cruz-Sampedro**

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In the first part of this talk we describe various standard results about the existence of smooth global solutions to the eikonal equation  $|\nabla u|^2 + V(x) = k^2$  on  $\mathbb{R}^n \setminus \{0\}$ ,  $k \in \mathbb{R} \setminus \{0\}$ , for potentials  $V$  of order zero; that is to say, that satisfy  $\partial^\alpha V(x) = (|x|^{-\alpha})$  as  $|x|$  goes to infinity, for all multi-indices  $\alpha$ . Then, we describe in more detail recent work of the author, joint with E. Skibsted, about the existence of smooth global solutions to the eikonal equation  $\nabla u G(x) (\nabla u)^t = 1$  on  $\mathbb{R}^n \setminus \{0\}$ , for a certain class of order zero metrics  $G$  on  $\mathbb{R}^n$ .

### **9.5 Application of the Method of Kalinay and Percus to Find Effective Diffusion Coefficients for Biological Channels**

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The study of diffusion in biological systems is a topic of research today. In this work we compute the effective diffusion coefficients,  $D = D(x)$ , for biological channels, from functional representations of  $D(x)$  obtained using the method developed

by Kalinay and Percus [J. Chem. Phys. 122, 204701 (2005); Phys. Rev. E 74, 041203, (2006)]. This method maps a diffusion problem in two or three dimensions to an effective one-dimensional description, using an infinite series of operators. In this work we obtain approximations at first and second order of these series, in order to obtain a finite representation of  $D(x)$ , which allows us to compare against other expressions as those suggested separately by Zwanzig [J. Phys. Chem. 96, 3926 (1992)], and Reguera and Rubí [Phys. Rev. E 64, 061106 (2001)]. Then we apply these results to biological channels with well-known morphologies, as gramicidin channel and the KscA potassium channel [Tieleman, et al., Quarterly Rev. Biophys. 34, 4(2001)].

## 9.6 Estimation of Patient Compliance Based on Limited Sampling Information

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Poor adherence to drugs has been brought to the limelight in the last decades, with focus on its drug-related problems. By adopting different approaches and strategies, numerous studies are now being dedicated to drug suboptimal use and its triad of problems.

The primary concern is directed towards the assessment of the therapeutic consequences inherited by deviations from ideal drug regimens. With the intention to establish the causal influence of drug intake irregularity on drug response in the forward direction, we previously developed a closed formalism relating compliance to pharmacokinetics (PK).

Since a patient's habitual temporal pattern generally exhibits a random temporal structure, its assessment calls for stochastic methodologies. The current ways of linking drug intake to PK naturally raise the so-called "inverse problem", which is around the issue of retracing the patient compliance scenarios based on limited clinical information.

Taking into account the inter and intra PK variability in a population of patients, we use a Bayesian methodology to retrace compliance scenarios having the sole knowledge of the last blood sampling information as reference.

Our developed approach allows, for the first time, to quantitatively assess possible compliance patterns having causal effects on given drug exposure.

## 9.7 A Mixed Finite Element Method with Exactly Divergence-Free Velocities for Incompressible Magnetohydrodynamics

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We introduce and analyze a mixed finite element method for the numerical discretization of a stationary incompressible magnetohydrodynamics problem, in two and three dimensions. The velocity field is discretized using divergence-conforming Brezzi-Douglas-Marini (BDM) elements and the magnetic field is approximated by curl-conforming Nédélec elements. The  $H^1$ -continuity of the velocity field is enforced by a DG approach. A central feature of the method is that it produces exactly divergence-free velocity approximations, guaranteeing the stability of the linearized systems within each Picard iteration. It also captures the strongest magnetic singularities. We prove that the energy norm error is convergent in the mesh size in general Lipschitz polyhedra under minimal regularity assumptions, and derive nearly optimal a-priori error estimates for the two-dimensional case. We present a comprehensive set of numerical experiments, which indicate optimal convergence of the proposed method for two-dimensional as well as three-dimensional problems.

This is joint work with Chen Greif and Dan Li (Department of Computer Science, University of British Columbia), and Dominik Schötzau (Mathematics Department, University of British Columbia).

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## 9.8 Enfoque Numérico Al Problema De Identificación De Dominio En Un Problema De Valor En La Frontera Con Condición Dirichlet

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La plática está dedicada al problema de identificar el dominio de definición, en dimensión dos, de una ecuación elíptica con condición Dirichlet en la frontera. La identificación se plantea como un problema de optimización, donde la función objetivo está definida sobre la clase de todos los conjuntos abiertos y conexos contenidos en un conjunto acotado en dimensión dos. Debido al trabajo pionero de Vladimir Sverak, se sabe que el problema de optimización está bien planteado si la clase

de conjuntos está equipada con la topología Hausdorff complementaria. Nosotros presentaremos el enfoque numérico del problema de identificación, utilizando para ello los siguientes elementos: la función distancia introducida por J. P. Zolesio, el concepto de ultracontractividad intrínseca definido por E. B. Davies y B. Simon, y la aproximación de problemas de optimización en el sentido de Gamma-convergencia. Finalmente, discutiremos las diferencias de nuestro enfoque con algunos trabajos que tienen fines similares.

Palabras clave: Optimización de forma, ultracontractividad intrínseca, función distancia, gama convergencia.

## 9.9 "5a Fachada", A System for Optimizing, Designing and Constructing Roofs With Light Russ-Based Steel to Conserve Energy and Materials

**Maximino Tapia<sup>1</sup>, Luz Angélica Caudillo<sup>1</sup>, Salvador Botello<sup>1</sup>, Héctor Hernández<sup>1</sup>, Juan Carlos Gómez<sup>2</sup>, Daniel Quiroz<sup>2</sup>, Marcos Escalante<sup>2</sup>, Eduardo Ayala<sup>2</sup>, Miguel Yáñez<sup>2</sup>**

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A virtual laboratory software that performs analysis, calculation, optimization of cold rolled steel truss, and the calculation of the quantity of materials used in the construction of the roof is presented. The software is equipped with an easy-to-use and friendly Graphic User Interface (GUI). Structural analysis considers self-weight, dead and alive loads to which the structure will be subjected in actual service conditions. In addition, wind effects and earthquake conditions for Mexico are considered in the design, according to regulations of the Commission Federal de Electricidad (CFE). The optimizer is based on entropy minimization methods with multiple constraints evaluating each of the structures by the stiffness method, which generates sparse matrices. The resulting system of equations can be solved with a variety of direct and iterative methods; state of the art algorithms have been implemented in the software to solve this resulting system. The AISI-ASD, which is the current regulation in Mexico to perform the assessment of the structure's efficiency, is implemented in the software.

The use of the existing legislation in the roof design, the implementation of state of the art algorithms for the optimizer and the matrix methods for calculating structures, coupled with the easy-to-use and friendly GUI, have resulted in a powerful software that creates affordable, reliable, secure and aesthetic housing solutions, favoring a large segment of Mexican society.

*Keywords:* Optimization, Light frame structures, Cold-formed steel

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## **9.10 Policies for Replacement of Water Meters in Mexico City Using Renewal Theory**

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In this paper we establish policies for replacement of water meters in Mexico City using the renewal theory. We show the current methodology used for such action in accordance with the implementation of a stochastic model with a general cost, we use a second model that consider the delay times to make the replacement. We do the calculations to obtain the optimal time of replacement of water meters in Mexico City.

## 9.11 Representation and Modeling Uncertainties In Fuzzy and Expert Systems

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In this report we discuss the methods of representation, processing and application of fuzzy and uncertain evaluations. We discuss the methods of representation of uncertainties in ordinal scales, as lexicographic evaluations and multisets and operations over them. Also the different methods to define parametric operations on fuzzy values suitable for tuning them in the process of optimization of fuzzy systems or in hardware implementation are considered. Application of these models and methods in expert systems and hardware fuzzy systems is discussed [1-4].

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## 9.12 Selecting Against Antibiotic-Resistant Pathogens: a Control-Theoretic Approach

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The rate at which pathogenic bacteria evolve resistance to antibiotics is dramatically decreasing the efficacy of current antimicrobial treatments. Different interventions have been proposed to control the emergence and spread of resistant pathogens in clinical settings, for instance by modifying drug prescription patterns. Previous studies have proposed that cycling antibiotics would reduce the selective pressures to any one antimicrobial class, but theoretical models have presented evidence for the optimality of antibiotic mixing. Using tools from control and systems theory, we show that aside from rare cases rotating antibiotics is indeed optimal. Furthermore, we study different single-host and epidemiological scenarios in order

to design effective antibiotic deployment protocols that select against drug resistant pathogens.

### **9.13 Chaos and MMOs in Singularly Perturbed Circuits with a Cubic Nonlinearity**

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We investigate bifurcations of two dual singularly perturbed circuits, each comprising a linear controlled source, nonlinear resistor and a small constant biasing source. During bifurcation of parameters the circuits' dynamics undergoes complex transitions between various stable and chaotic modes, including the mixed mode oscillations (MMOs), period doubling bifurcations and chaotic responses. Canard solutions are present in most cases. The circuits are described by a relatively simple singularly perturbed system of equations (two linear and one nonlinear) with five parameters. Two parameters describe the nonlinear resistor, another parameter defines a linear controlled element, fourth parameter comes from a small constant voltage (or current) source and the fifth parameter is a linear resistance (or conductance). Our analysis is based on numerical simulations from which several intriguing responses of the circuits are obtained.

Keywords: Singularly perturbed systems, DAEs, bifurcations, MMOs, chaos, oscillations.

### **9.14 Modeling the Adaptive Immune Response in HBV Infection**

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The aim of this work is to investigate a new mathematical model that describes the interactions between Hepatitis B virus (HBV), liver cells (hepatocytes), and the adaptive immune response. The qualitative analysis of this model leads us to different aspects of the outcome of the adaptive immunity, which here is referred to Cytotoxic T Lymphocytes cells (CTL cells) and the antibodies. These outcomes are (1) a disease free steady state, which its local stability is characterized as usual by  $R_0 < 1$  (2) and the existence of four endemic steady states when  $R_0 > 1$ . The local stability of these steady states depends on functions of  $R_0$ . Our study shows that although we give conditions of stability of these steady states, not all conditions are feasible. This rules out the local stability of two steady states. The conditions of stability of the two other steady states (which represent the complete failure of the adaptive immunity and the persistence of the disease) are formulated based on the domination of CTL cells response or the antibody response. To illustrate our results, numerical simulations are also presented.

### 9.15 Hair Root Initiation Model: a Mathematical Approach

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Amongst a large list of processes for plants, osmosis is an important example. That is, under a humid soil regime, mineral salts and water can enter through their roots make them swollen; because of this and advection, their root hairs tend to move from high water concentration regions to lower ones. In consequence, the root moves through soil, as a result, more surface area between roots and soil appears which implies a better absorption of nutrients. However, there is no full understanding how hair root developments.

Nevertheless, Rho small GTPases family-proteins in charge to transmit chemical signals outside the cell, and causing changes inside it-contributes strongly in many biological processes such as wound healing, morphogenesis, locomotion, division and, particularly, intracellular location of patches which produces local cell outgrowths amongst others. Furthermore, Jones et. al (2009) experimental studies confirm that a plant hormone called auxin plays also an important role in the plant life cycle, besides that regulates root hair outgrowing.

On the other hand, a mathematical approach to understand the dynamics of root hair initiation has been considered by several authors, for instance Payne & Grierson (2009) model it as a reaction-diffusion system which describes these different biochemical interactions. Particularly, they have postulated that bounded and unbound G-proteins, known as ROPs, diffuse at very different rates. Besides, they also take into account the auxin hormone presence-which also plays an important role in many cell development processes-as a spatially distributed gradient; indeed, experimental evidence can be found in some studies, for instance Jones et al. (2009) and Grieneisen et al. (2007).

We take their point of view and analyze it applying the Lyapunov-Schmidt reduction method in order to provide a suitable criticality condition for a driven diffusion instability where length and overall auxin rate are gathered in a single parameter which bifurcation existence values are exhibited. Additionally, we also apply asymptotic methods to give solution properties when the auxin protein presents a spatial decreasing gradient for a 1D domain. That is, the system studied is given by

$$\begin{aligned} \text{Bound-active ROP: } u_t &= D_1 u_{xx} + k_2(x)u^2v - (c + r)u + k_1v, \\ \text{Unbound-inactive ROP: } v_t &= D_2 v_{xx} - k_2(x)u^2v + cu - k_1v + b, \end{aligned}$$

where  $b$  is the ROP binding rate,  $k_1$  the activation rate, the catalytic acceleration is modelled by  $k_2(x)$ , the active ROP required to develop other complexes which helps to membrane cell softening,  $r$ , the deactivation rate is represented by  $c$ , and the diffusion coefficients,  $D_1$  and  $D_2$ , are such that  $D_1 \ll D_2$ . Homogenous Neumann boundary conditions are taken into account.

## **9.16 Neonatal Seizure Detection using Blind Adaptive Fusion**

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Seizures are the result of excessive electrical discharges of neurons, which usually develops synchronously and happens suddenly in the central nervous system. It is critical to recognize seizures in newborns, since they are related to other significant illness quite often. Seizures are also the initial sign of neurological disease and a potential cause of brain injury [1]. Clinically, an EEG monitoring system is used to record all the activities of the patient's brain. Some particular patterns in the recordings, such as rhythmicity and periodicity, represent the seizure occurrences. A long-term monitoring usually generates a huge amount of data, but only a small portion is useful. Therefore, automated detection of seizures in newborns became an interesting field of biomedical research. Several detection algorithms has been proposed, which used different biomedical signal processing techniques. Based on the rhythmicity of the neonatal EEG seizures, the authors of [2] performed analysis on the autocorrelation function of the EEG signals. Frequency spectral analysis is used in [3] to detect the rhythmic discharges. The algorithm proposed in [4] checked the complexity of neonatal EEG signal in order to identify newborn seizure activities.

One of the main difficulties with seizure detection lies in the fact that the statistical properties of the underlying EEG signal are time-dependent and vary significantly from patient to patient. As a consequence it is rather difficult to evaluate the existing seizure detectors since all of them are based on mathematical models whose performance (specificity and selectivity) varies significantly based on a data set. To this purpose we propose to combine the existing single channel detectors by extending our previous results on blind multichannel information fusion [5] [6]. The advantage of the proposed technique is that it does not require a priori knowledge on probability of occurrence or detector performance. We propose a computationally efficient algorithm in which the probability of seizure detection, specificity and selectivity are estimated as a part of an initial phase. We first formulate the set of nonlinear equations consisting of unknown priors and performance measures (specificity and selectivity) and then estimate them using the corresponding multivariate distribution, maximum likelihood estimation and actual count of decisions made on different detectors. We then present the analytical expression of over- all error probability when the true values of the parameters are given and explore the effect of our blind algorithm to the overall seizure detection. We also propose computationally efficient time-dependent algorithm in which the unknown parameters are estimated if the statistical properties of the EEG signal change causing degradation in the overall performance. Finally, we evaluate the applicability of the proposed algorithm using both synthetic and real neonatal EEG data.

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## 9.17 Modeling of Hydrogen Embrittlement Cracking in Pipelines Under Big Pressures

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During the transport of oil and hydrocarbons, dissolved hydrogen can penetrate into the walls of pipelines, frequently causing delaminating of the metal. Hydrogen absorbed by a metal is typically dissolved in the lattice in the proton form. Some of the protons reach the surface of a pre-existing or freshly created cracks where they recombinate with electrons and form molecular hydrogen in the crack cavity. Because usually the molecular form of hydrogen is thermodynamically more stable, this process leads to accumulation of gas hydrogen inside the crack. Hydrogen being accumulated inside the delamination cavity creates pressure which eventually leads to the damage of the pipeline. The focus of this study is the modeling of how the radius of delamination grows with respect to time. The modeling requires the solution of the coupled problem of elasticity theory about the crack opening under gas pressure and diffusion theory of gas diffusion into the crack cavity. The equation of state for the ideal gas is first used; however, this is only accurate for low pressures. However, while gas is accumulated inside the crack, its pressure becomes big enough that the gas cannot be considered ideal anymore. In this study, we apply the van der Waals equation, which is valid for high pressures. While the subsequent calculations are somewhat more cumbersome than for the ideal gas case, they are still straightforward that allow obtaining the close-form solution for the crack size,  $a(t)$ , depending on time, although only in implicit form. The results reveal some intriguing features worth checking experimentally. Under big hydrogen pressures inside the cracks, the latter do not grow at the constant speed as for case of the ideal gas, but accelerate first. However, with time, large pressure driven cracks are slowing down, and in asymptotic approximation, as time is approaching infinity,

they also start growing at the constant speed, besides at exactly the same as the hydrogen driven cracks under the ideal gas conditions.

## 9.18 Patchy Solutions of Hamilton Jacobi Bellman Partial Differential Equations

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We compute solutions to the HJB PDE using a combination of techniques. First the solution is computed in a patch around the origin using the power series approach of Al'lbrecht. The patch is a sublevel set of the computed optimal cost. Then the solution is computed in a set of patches surrounding the Al'lbrecht patch using Cauchy Kovaleski techniques. Then the solution is computed in a second set of patches surrounding the first set and so on. We believe that the method is higher order.

## 9.19 On Reconstruction of Temperature-Dependent Parameters in Multiphysics Phenomena

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In this investigation we develop a computational framework for optimal reconstruction of isotropic constitutive relationships between thermodynamic variables based on measurements obtained in a spatially-extended system. In other words, assuming the constitutive relation in the following general form

$$\begin{bmatrix} \text{thermodynamic} \\ \text{flux} \end{bmatrix} = k(\text{states variables}) \begin{bmatrix} \text{thermodynamic} \\ \text{"force"} \end{bmatrix} \quad (2.1)$$

our approach allows us to reconstruct the dependence of the transport coefficient  $k$  on the state variables consistent with the assumed governing equation(s). Constitutive relations in the form (1) arise in many areas of non-equilibrium thermodynamics and continuum mechanics. A specific application motivating this research is related to modeling thermo fluid phenomena occurring in liquid metals during welding. The material properties of many alloys are known to depend on the temperature in a way which is difficult to measure directly, or predict on theoretical ground. Therefore, in this work we propose and validate a computational approach for estimation of

such constitutive relations based on available measurements. To fix attention, but without loss of generality, in the present investigation we focus on the problem of a reconstruction of the temperature dependence of the viscosity coefficient  $\mu(T)$  in the momentum equation (Navier-Stokes equation) where the temperature  $T$  is governed by a separate energy equation (in 2D or 3D):

$$\begin{aligned} \partial_t \mathbf{u} + \mathbf{u} \cdot \nabla \mathbf{u} + \nabla p - \nabla \cdot [\mu(T) [\nabla \mathbf{u} + (\nabla \mathbf{u})^T]] &= 0 \quad \text{in } \Omega, \\ \nabla \cdot \mathbf{u} &= 0 \quad \text{in } \Omega, \\ \partial_t T + \mathbf{u} \cdot \nabla T + \nabla \cdot [k \nabla T] &= 0 \quad \text{in } \Omega, \end{aligned} \quad (2.2)$$

subject to appropriate Dirichlet or Neumann boundary and initial conditions, where  $\Omega \in \mathbb{R}^n$ ,  $n = 2, 3$  is the spatial domain on which the problem is formulated. The main challenge in the present problem is that, in contrast to "classical" parameter estimation problems in which the coefficient is a function of space, here we address estimation of state-dependent, and therefore nonlinear, constitutive relations. The specific inverse problem we address in this investigation is formulated as follows. Given a set of "measurements"  $\{\tilde{T}_i\}_{i=1}^M$  of the state variable (temperature)  $T$  at a number of points  $\{x_i\}_{i=1}^M$  in the domain  $\Omega$  (or along the boundary  $\partial\Omega$ ), we seek to reconstruct the constitutive relation  $\mu(T)$  such that solutions of problem (2) obtained with this reconstructed function will fit best the available measurements. An approach commonly used to solve such inverse problems consists in reformulating them as minimization problems. This is done by defining the cost functional  $\mathcal{J} : \mathbb{R} \rightarrow \mathbb{R}$  as

$$\mathcal{J}(\mu) \triangleq \frac{1}{2} \sum_{i=1}^M [\tilde{T}_i - T(x_i; \mu)]^2, \quad (2.3)$$

where the dependence of the temperature field  $T(\cdot; \mu)$  on the form of the constitutive relation  $\mu = \mu(T)$  is given by governing system (2). The key ingredient of the minimization algorithm is computation of the cost functional gradient  $\nabla_{\mu} \mathcal{J}(\mu)$ . We emphasize that, since  $\mu = \mu(T)$  is a continuous variable, the gradient  $\nabla_{\mu} \mathcal{J}(\mu)$  represents in fact an infinite-dimensional sensitivity of  $\mathcal{J}(\mu)$  to perturbations of  $\mu(T)$ . In our presentation we will show that this gradient can be determined based on suitably defined adjoint variables (Lagrange multipliers) obtained from the solution of the corresponding adjoint system which is at the heart of the proposed reconstruction algorithm. Since in general inverse problems often tend to be ill-posed, care must be taken to perform suitable regularization. In presentation we will review implementation of this approach together with computational results obtained for the problem (2) and another simple model problem. In addition, we will also introduce a systematic approach to modify the experimental set-up so that the constitutive relation can be estimated over desired range of the temperature.



## 9.20 Computational Modeling of Temperature Profiles of a Combustion Tube with Temperature Dependent Thermal Conductivity

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In situ combustion (ISC) is an oil recovery method. In order to evaluate if a reservoir is a good candidate for ISC, a combustion tube test is required. A mixture of oil, brine and grounded rock from the reservoir is put inside a thermal isolated steel tube. At the top, a constant air flux is injected producing a combustion front that propagates with constant speed. Thermal transducers along the tube monitor the temperature distribution. The heat produced decreases the oil viscosity while the CO<sub>2</sub> and vapor push the fluids out through a valve at the bottom [1]. Using the model proposed by Penberthy and Ramey [2], the heat diffusion equation with temperature dependent conductivity is solved for a finite domain. Finite differences and Newton's method are used to build a numerical model which was programmed in MATLAB. A mixture temperature dependent conductivity model is used. The conductivity variation effects on temperature profile were studied and compared with the analytical solution for constant thermal conductivity. An improved fitting is obtained. This model allows the matching of the thermal conductivity with independence of mass transport. It also allows identify the zones of the temperature profile where deviations occur due to vaporization, condensation and reactions.

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## 9.21 Efficient Calculation of Frequencies of Extended Molecular System with the Mobile Block Hessian Method

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Normal mode analysis (NMA) is a well-known technique to estimate vibrational frequencies of molecular systems [1]. The technique consists of diagonalizing the second derivative matrix of the potential energy with respect to the atomic coordinates after mass-weighting and yields the normal modes of vibration and the

eigenfrequencies. In hybrid quantum mechanical/classical mechanics (QM/MM) descriptions, however, the calculation of the analytical second derivative matrix (Hessian) is the bottleneck when an electrostatic embedding scheme is employed [2]. Even with a small number of QM atoms in the system, the presence of MM atoms boosts up the computational cost: the long-range Coulomb interactions require that additional coupled perturbed self-consistent field (CPSCF) equations need to be solved for each MM atom displacement.

In order to decrease the number of CPSCF equations, we have combined the mobile block concept of the Mobile Block Hessian (MBH) approach [3,4,5] with the QM/MM description. Blocks are allowed to translate and rotate as rigid bodies during the vibrational analysis while their internal degrees of freedom are frozen. MBH reduces both the CPU time and the memory requirements compared to the standard full Hessian QM/MM analysis, without the need to use a cut-off distance for the electrostatic interactions.

In this presentation, we show how MBH is established for QM/MM calculations with mobile blocks in the MM region. The parallel implementation in the Q-Chem/CHARMM package [6,7] is illustrated with the chorismate mutase example. In addition, the drug bortezomib, used for cancer treatment of myeloma [8], has been studied as a test case with multiple MBH block choices and both a QM and QM/MM description. The results show that MBH within the QM/MM description is not only a computationally attractive method, but also produces accurate results.

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## 9.22 Computational Modeling of a Micro-Mixer: an Application of Navier-Stokes and Diffusion Equations

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A micro-mixer is a micrometric device (a micro-electro-mechanical system or MEMS) capable to obtain a uniform distribution from several components of a mix, in a short period of time. Such components can be fluids with different concentrations coming into the micro-mixer and, by electroosmotic effects and physical

perturbations on their path, are mixed forming another fluid with uniform density at the outlet. Due to the low Reynolds number used, flows are laminar. Some of their applications appear in biochemical microlaboratories (lab-in-chip), or in the manufacturing of micro-pumps and micro-valves. Physical laws modeling a micro-mixer are those of fluid mechanics (Navier-Stokes eqs.), as well as the balance equation for current density (diffusion eq.), which comes from applying the Helmholtz-Smoluchowski relation to establish certain boundary conditions. This paper presents the design of a micro-mixer following electroosmotic principles in a geometry with obstacles for the fluid. Results from a time dependent analysis are shown. Furthermore, known reports from literature are verified to validate the mathematical method. Partial differential equations resulting are solved with the finite element method.

*Keywords:* Micro-mixer, MEMS, Navier-Stokes equations, Diffusion equation, Finite element.

### 9.23 Robust Optimization for Robot Positioning by Using a Hybrid Optimizer: Estimation of Distribution Algorithm and Dogleg

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In robotics, solving forward kinematics problem for parallel robots usually is more difficult and time consuming than their serial counterparts, meaning that no explicit equations for pose (position and orientation) parameters can be found. The problem is stated as follows: given the joint variables one wants to compute the Cartesian variables, namely the pose (position and orientation) of the mobile platform. Most of the time, the forward kinematics problem requires to solve a non-linear system of equations. In addition, this system could be nonconvex, thus, Newton or Quasi-Newton based solvers get trapped on local minima. The capacity of such kinds of solvers of finding an adequate solution strongly depends on the starting point. A well known problem is the selection of such starting point, which requires a priori information about the neighboring region of the solution. In order to circumvent the mentioned issue, this article proposes an efficient method to select and to generate the starting point based on probabilistic learning. Several experiments and discussion are presented to show the method performance. The method successfully avoids to get trapped on local minima without need of human intervention, which increases the robustness of the solver when compared with a single quasi-Newton approach (Dogleg). This proposal can be extended to other structures, to any non-linear system of equations, and of course, to non-linear optimization problems.

## 9.24 Multiobjective Optimization using Estimation of Distribution Algorithms Based on The Empirical Selection Distribution

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Multiobjective optimization refers to the solution of minimization/maximization problems which involve several conflicting objective functions. In order to solve these problems, the first need is an optimality criterion, a widely used criterion is the Pareto optimality, such criterion defines a set of solutions as efficient or optimal instead of a single point. To find the Pareto optimal set it is necessary a method or algorithm. A family of algorithms which have shown impressive results to deal with multiobjective problems are evolutionary algorithms. Evolutionary algorithms (EAs) naturally work with a set of candidate solutions (population). They iteratively intend to find and to preserve a set of Pareto optimal decision vectors. In addition, EAs are designed to tackle quite hard optimization problems which can not be approached by gradient based optimizers, it means: non-convex problems with multiple local optima (in this case local Pareto optimal sets). The Estimation of Distribution Algorithm (EDA) is a kind of EA which uses an explicit probability model for approximating the optimal set. Each generation, the EDA samples the population from a probability distribution, evaluates the population, selects a subset of solutions, and re-estimates the probability distribution by using the selected set. The selected set is chosen in such a way that the probability distribution is biased to sample more intensively the known regions with the best objective function values. EDAs can approach the same kind of problems than other EAs such as genetic algorithms and evolutionary strategies, with the advantage that EDAs can use information about variables correlations, thus, a better performance than other EAs is expected when highly correlated problems are approached. A new selection step has been recently proposed for EDAs, it is called: the Empirical Selection Distribution (ESD). The ESD has shown that it can improve state of the art EDAs by simply substituting the selection step. The main improvements are: less objective function evaluations and better optimum approximation than the standard EDA. The ESD was presented for mono-objective problems and has not been used for multiobjective optimization. This article proposes a method to insert the ESD in multiobjective EDAs based on a Pareto optimality derived criterion: the Pareto ranking. Practical experiments and results are presented and discussed to show the advantages of introducing the ESD in multiobjective EDAs.

## 10 General Session - 2

### 10.1 An Agent-Based Model With Drift and Cross-Immunity for Influenza

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An agent-based model is used to describe the dynamics of influenza drift and cross-immunity in host populations with different characteristics. Each different mutation of the virus will be represented as a point in a phylogenetic map, and a strain of the virus by a region in that map. Each individual has a history of all his previous infections, represented by a vector consisting of points in the map. At a given time each infected individual will have contact with other individuals of the population. The probability that this contact results in an infection, depends on how far the virus is to the closest point in the history of the individual to be infected (cross-immunity). If the contact is effective, the individual will be infected for the next time period. However, since the virus is going to mutate in his body, for the next time period the active mutation will be one that is not the same that got him infected, but very close in the map to it (drift). Special attention will be given to the infection of influenza in the tropics, since this area has not been well characterized by mathematical models. Patterns similar to the ones observed in the tropics are obtained in the simulations with low values of contact or infection rates.

### 10.2 Seismic Wave Propagation in Fractured Media: a Discontinuous Galerkin Approach

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#### 1 Introduction

A realistic model of the subsurface should include fractures; these can be observed in many scales, from faults to micro-cracks. In particular, azimuthal velocity anisotropy has been observed in many regions, and this has been attributed to aligned vertical micro-cracks (Schoenberg and Douma, 1988). For this reason there has been recently an increased interest in the characterization of fractured media in the oil industry (e. g. Schoenberg, 1980; Schoenberg and Douma, 1988; Liu et al., 2000; Sen et al., 2007; Zhang and Gao, 2009).

There are two main approaches to incorporate the effects of fractures: (1) Using equivalent medium theories or (2) using a numerical scheme to simulate the fractures. There have been many theories proposed in the literature that predict the effective media parameters associated with a particular fracture distribution (e. g. Mavko et al., 1998, and references therein). All of these models make different assumptions about the fractures, in particular they usually assume small, circular,

non-intersecting cracks. The advantage of the equivalent medium theories is that they provide analytic expressions for the media parameters as a function of the fracture parameters. On the other hand, they have limited applicability because of the large number of assumptions. It is interesting to note that these models make different predictions for the effective P- and S-wave velocities when the crack density is increased (Saenger et al., 2004).

Regarding the numerical schemes to incorporate the fractures, there are many approaches that have been proposed in the literature. Examples of these are (1) to use locally an effective medium (Vlastos et al., 2003), (2) to incorporate locally a low velocity and low density inclusion into a finite difference scheme (Saenger and Shapiro, 2002; Saenger et al., 2004), and (3) To explicitly use a displacement discontinuity condition using the linear-slip model (Zhang, 2005; Zhang and Gao, 2009). The main advantage of the numerical schemes is that they require few assumptions and therefore they have a broad applicability and are useful to validate the equivalent medium theories. In particular, the approaches based on the linear-slip model require the least number of assumptions. On the other hand, they require significant effort to generate a computational mesh that incorporates the fractures and to solve the resulting linear system.

## **2 Numerical Approach**

One of the goals of this research is to perform numerical simulations of elastic wave propagation in models with fractures using a highly accurate numerical method. The advantage of the numerical simulations is that they require fewer assumptions than the analytical models that have been proposed to estimate the effective media parameters and therefore are useful to validate these models. Furthermore, the numerical simulations can be performed using more general and realistic physical models than the ones assumed to estimate the effective media parameters.

In order to do this, we will use the Linear-Slip Model (LSM), which prescribes a linear relation between the traction vector at the fracture and the magnitude of the discontinuity in the displacement field Schoenberg (1980). This model has been validated by laboratory experiments in Hsu and Schoenberg (1993).

We incorporate LSM into the elastic wave equation using the Discontinuous Galerkin Method (DGM), which is a generalization of the finite element method that allows for the approximating functions to be discontinuous at the element's interfaces. This method is particularly suited to incorporate fractures or faults because these are simulated as discontinuities in the displacement field. The continuity or linear slip are imposed weakly with some extra terms in the weak formulation. There are many different ways to weakly impose the continuity, which give rise to the many different formulations of DGM. We focused on the interior-penalty, or primal, formulations of DGM (IP-DGM). The accuracy and stability of this method for wave propagation has been studied in De Basabe et al. (2008) and De Basabe and Sen (2010).

## **3 Concluding Remarks**

We have developed a formulation of IP-DGM that can include fracture discontinuities in the domain using LSM. We consider three possible applications of this formulation:

1. To validate the analytical results for the reflection coefficients at a linear-slip discontinuity, for example those presented in van der Neut et al. (2008),
2. To validate the effective media theories, for example those summarized in Mavko et al. (1998),
3. To obtain the seismic response of fractured media with more complicated geometries, for example with intersecting fractures or with a high density of fractures, in which cases the effective media theories do not apply.

### 4 Acknowledgments

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### **10.3 Hodge Decomposition and Maxwell's Equations**

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In this talk we propose a new numerical approach for two-dimensional Maxwell's equations that is based on the Hodge decomposition for divergence-free vector fields. In this approach an approximate solution for Maxwell's equations can be obtained by solving standard second order scalar elliptic boundary value problems. We illustrate this new approach by a  $P_1$  finite element method. We will present both theoretical and numerical results. This is joint work with Susanne C. Brenner, Zhe Nan and Li-yeng Sung.

### **10.4 The Role of Symmetric and Asymmetric Division of Cancer Cells in Developing Drug Resistance**

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Often, resistance to drugs is an obstacle to a successful treatment of cancer. In spite of the importance of the problem, the actual mechanisms that control the evolution of drug resistance are not fully understood. Many attempts to study drug resistance have been made in the mathematical modeling literature. Clearly, in order to understand drug resistance, it is imperative to have a good model of the underlying dynamics of cancer cells. One of the main ingredients that has been recently introduced into the rapidly growing pool of mathematical cancer models is stem cells. Surprisingly, this all-so- important subset of cells has not been fully integrated into existing mathematical models of drug resistance.

In this work we incorporate the various possible ways in which a stem cell may divide into the study of drug resistance. We derive a new estimate of the probability of developing drug resistance by the time a tumor is detected, and calculate the expected number of resistant cancer stem cells at the time of tumor detection. To demonstrate the significance of this approach, we combine our new mathematical estimates with clinical data that is taken from a recent six-year follow-up of patients receiving imatinib for the first-line treatment of chronic myeloid leukemia. Based on our analysis we conclude that leukemia stem cells must tend to renew symmetrically as opposed to their healthy counterparts that predominantly divide asymmetrically.



## 10.5 Computational Modeling of ESWT

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Extracorporeal Shock Wave Therapy (ESWT) is a noninvasive treatment for bone fractures that fail to heal, necrotic wounds and strained tendons. It is similar to lithotripsy, a non-surgical treatment for kidney stones [7]. In this treatment a shock wave is generated in water and then focused using an acoustic lens or reflector so the energy of the wave is concentrated in a small region. This technique has been used since the 1980's, but the underlying biological mechanisms are not well understood. We have computationally investigated shock wave propagation in ESWT by solving a Lagrangian form of the isentropic Euler equations in the fluid and linear elasticity in the bone using high-resolution finite volume methods [1].

This work differs from prior modeling of ESWT in that we are solving a full three-dimensional system of equations so we can handle complex bone geometries. This formulation of the equations enables us to consider shear stresses generated within the bone, which are important for understanding healing [8, 5]. We provide details on the set of equations we use to model the wave propagation, as well as results validating this approach [3]. We also present the equations for photoelasticity that we have solved in order to more accurately compare our results to laboratory experiments [6, 1]. This approach is valuable for comparison of shock wave propagation in birefringent materials [9, 4]. Our modeling efforts have been used to investigate the treatment of bone fractures and heterotopic ossifications [2].

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## 10.6 Optimization and Adaptive Fitting of Mixed-Effects Models with Correlated Random-Effects

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Mixed-effect models (MEMs) have been widely used in longitudinal data analysis as they allow for correlations among repeated measurements from the same unit. How to best model random effects of MEMs is still an important and unresolved issue in practice. For example, the non-convergence rate was about 20 percent on average in simulation studied by current R algorithm. We propose a data-driven algorithm to adaptively fit the MEMs that reduces the correlation among random effects in transformed parameter space. Simulations show that the proposed algorithm significantly improves the nonconvergence rate (down to 1 percent), the reduction of correlation among random effects and the fitted log-likelihoods. Two real data sets are used to illustrate the application of this algorithm.

*Keywords:* Longitudinal data analysis, Convergence on the boundary, Covariance matrix, Condition number, Data-driven fitting.

## 10.7 BAK-Pack: Solve Sparse Linear Systems with Krylov Subspace Methods

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In recent years, several branches of applied mathematics, such as discretization of partial differential equations of multi-physics problems, require more and more accuracy. This has lead to an accelerated increase in the number of unknowns and numerical difficulty involved in the solution of the sparse linear systems arisen in such applications. Traditionally the methods cataloged as direct had predominated in the solution of these sparse linear systems. Iterative methods have been emerging in recent years as an advisable option in order to carry out this task, which in turn consumes a large amount of the computing time used in industrial, scientific and applied computations. Krylov subspace methods, commonly known as Krylov

projection methods, have reached a considerable increase in use and improvement; also accelerating techniques, such as preconditioning, have been receiving much attention.

The objective of this work is to present in an concise, brief and intuitive manner, the underlying theory of Krylov subspace methods with some preconditioning techniques. As an implementation of this theory, we present the BAK-Pack open-source software, which is a multi-language, robust, self contained and modularized, set of routines that implements several Krylov subspace methods to approximate the solution of linear systems, supposed to be large and preferable sparse. These easy to use routines include the most classical and popular methods of this kind, but also very specialized ones, that constitute the state of the art of this topic. Since the most computational consuming operation in this framework is the multiplication of a matrix or its transpose by a vector, several subroutines are included to carry this task efficiently for a great variety of sparse matrix storage formats. Also preconditioning techniques have been implemented and added to the package, which includes classical iterative methods, incomplete factorizations, and polynomial preconditioning.

We show results obtained by several methods implemented in the yet mentioned package, applying different preconditioning techniques to matrices that come from a great variety of fields, giving as a result matrices with different numerical and sparsity properties. The order of these linear systems goes from few thousands up to tens of millions. These solutions have been carried out in a serial computation environment. Also we present results of some interesting test cases up to hundreds of millions carried out in a parallel computing environment with distributed memory, making special emphasis in the potential use of this package in the high performance computing context.

### 10.8 Risk-Sensitive Second and Third Degree Optimal Filtering Design and Applications

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The risk-sensitive filter design problem for polynomial systems of second and third grade drift terms and intensity parameters multiplying diffusion terms in the state and observations equations with respect to the exponential mean-square criterion is considered for stochastic Gaussian systems. The closed form optimal filtering algorithm is obtained using quadratic value functions as solutions to the corresponding Focker- Plank- Kolmogorov equation. The performance of the obtained risk-sensitive filter for stochastic second and third degree polynomial systems is verified in a numerical example against the optimal polynomial for second and third degree

filter through comparing the exponential mean-square criteria values. The simulation results reveal strong advantages in favor of the designed risk-sensitive algorithm for all values of the intensity parameters.

## 10.9 Comparison of Different Solution Strategies for Structure Deformation using Very Fine Discretization

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Modeling elastic deformation of mechanical structures with the finite element method could lead to solve sparse linear systems of hundreds of millions of equations when high accuracy is required. This article presents a study about the solution of this kind of problems using meshes up to a hundred million of elements by using a hybrid parallelization, a combination of distributed and shared memory models.

In order to distribute the computational workload among processors a domain decomposition technique is applied by using the Schwarz alternating method. According to this method domain partitions are overlapped in such a way that the solution of a partition is used as the Dirichlet boundary condition of the adjacent partition. Thus, boundary conditions (displacements) are interchanged among all partitions that share an overlapped area, this process is repeated until global convergence is reached. This interchange of information is done using distributed memory.

Solving the local finite element problem in each partition requires the solution of a linear system of equations. This article presents a comparison and discussion about Schwarz domain decomposition using different solving methods for local systems. The direct solvers discussed are Cholesky and LU factorizations, on the other hand the iterative solver contrasted is conjugate gradient with and without preconditioning (Jacobi and incomplete Cholesky and LU factorizations). These methods vary in memory requirements and difficulty of their parallelization using shared memory.

Several strategies are applied in order to improve the efficiency of Cholesky and LU factorizations, such as compressed matrix storage, matrix reordering and symbolic Cholesky factorization, this reduce factorization fill-in. The same strategies are applied to the construction of incomplete preconditioners.

Due to the fact that the stiffness matrix remains constant through in all the process, global (Schwarz) iterations with direct solvers are faster than the iterative counterparts, because factorization is done only once, but their memory requirements are several times bigger than iterative solvers.

Experiments and comparative results about solution time and memory usage are presented. Different configurations for domain decompositions are used, for instance, using many small partitions each one using a single processor or less partitions using several processors that share memory. Each configuration is tested

using different direct and iterative solvers, also, several test are conducted varying the level of the incomplete factorizations of the preconditioners to control their memory usage.

This kind of experiments becomes very useful when one is looking for an adequate compromise between solution time and memory requirements. The solvers are implemented using MPI for distributed memory, and OpenMP for shared memory parallelization. Experiments are carried out by using a Beowulf cluster with 200 processors.

Keywords: Partial differential equations, structure deformation, domain decomposition, parallel computing, finite element method, Schwarz alternating method, direct solvers, preconditioned conjugate gradient.

### 10.10 Estimation of Lane-Change Parameters for a Traffic Flow Model in a Multi-Lane Street

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Mathematical models for traffic flow are usually dependent on several variables of different kinds (physical constraints, behavioral parameters, stimulus-reaction coefficients, etc.). Some of those may be obtained using real data from experiments or specially designed measure devises, in other cases they are obtained by further assumptions imposed in the phenomenon and some times even as “good guessing”. In our work we define a model space for a special kind of multi-lane street and use the real behavior of the street for the estimation of the model variables, in particular we are interested in those variables related with the change-lane behavior, which seems to be the main cause of traffic jams in such kind of streets.

### 10.11 New Models for the Piece-Mold-Machine Manufacturing Planning

**M. A. Saucedo-Espinosa<sup>1</sup>, O. J. Ibarra-Rojas, Y. A. Rios-Solis**

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This project deals with a real manufacturing process of pieces, which are produced with molds and these molds are mounted on machines, as for example, in the plastic injection molding industry. Our purpose is to describe the process by using two new models: an integer linear programming formulation and an integer quadratic constraint programming formulation. Both formulations integrate the most important characteristics of the process in order to determine the quantities of

pieces to be produced, as well as the allocation of molds to machines. Such characteristics include the involved setup time between jobs, dedicated parallel machines, dedicated molds and different production speed for each pair (piece-mold).

In the plastic injection molding industry, a company has a demand for different types of pieces that needs to be fulfilled. When a company fails to meet its demand, it is often forced to buy products to other companies so as not to lose customers. We consider the objective of maximizing the weighted fulfilled demand since we seek to minimize the weighted non-fulfilled demand. Thus, the pieces to buy to other companies will be less expensive.

The proposed formulations differ from others in literature as they do not restrict a mold to be mounted on a single machine. The lack of such a restrictive condition represents an improvement and a more realistic description of the production process itself. Execution time and relative average deviation comparisons with a model available in literature are presented, by using a branch and bound method. Preliminary results appear to demonstrate a lower execution time for the proposed integer linear programming formulation. The instances were generated, except for the weight of pieces, based on information provided by a real manufacturer of plastic products.

## **10.12 The Hidden Energy in Irreversible Fluctuations as the Origin of Noise Induced Phenomena: Stochastic Focusing**

**Lisa Bishop<sup>1</sup>, Hong Qian**

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The application of stochastic models to biochemical reaction networks has led to the discovery of a wide range of noise-induced phenomena. Here we address one such phenomena: stochastic focusing (SF). SF highlights a system whose fluctuations allow for a superior performance in contrast to the same system considered deterministically. We analyze this system using chemical master equations to find approximations to the expected value and find that the presence of hidden free energy in the underlying fluctuations is required for the presence of these noise-induced phenomena.

### 10.13 Elliptic Super Regularization for Nonlinear Inverse and Ill-Posed Problems

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Elliptic Super Regularization, introduced by Browder and Ton, relies on an interesting idea of embedding the original problem into a more regular space and to perform the regularization into this new space. Recently, this approach has also been used in obtaining novel results in degree theory for generalized operators. This talk will focus on employing the elliptic super regularization for nonlinear inverse and ill-posed problems. The main results will be discussed in the context of highly ill-posed variational problems. We will show that elliptic super regularization can give a new technique to study the nonlinear inverse problem of identifying discontinuous coefficients in partial differential equations.

### 10.14 A Classification of Infinite Dimensional Walrasian Economies and the Economic Crisis

**Elvio Accinelli, Martín Puchet**

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We consider pure exchange economies whose consumption spaces are Banach Lattices. Utility functions are strictly concave, Gateaux differentiable, and not necessarily separable. Following the Negishi approach and by using the excess utility function we introduce the set of social equilibria. We show that there exists a bijective correspondence between this set and the set of Walrasian equilibria. By transforming the infinite dimensional problem of finding Walrasian equilibria into an equivalent finite dimensional problem of finding social equilibria, we allow ourselves to use techniques of smooth functional analysis. We show that a suitable large subset of economies are regular and its equilibrium set is a Banach manifold. Finally, we focus on the complement of this set, i.e. the set of singular economies, and we analyze its main characteristics, among them those of being the causes of the economic crises.

Keywords: Negishi approach, Banach spaces, Banach manifolds, singular economies.

## 11 Poster Session

### 11.1 New Models for the Piece-Mold-Machine Manufacturing Planning

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In the plastic injection molding industry, a company has a demand for different types of pieces that needs to be fulfilled. When a company fails to meet its demand, it is often forced to buy products to other companies so as not to lose customers. We consider the objective of maximizing the weighted fulfilled demand since we seek to minimize the weighted non-fulfilled demand. Thus, the pieces to buy to other companies will be less expensive.

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### 11.2 Numerical Solution of the Poisson-Nernst-Planck on Fuel Cells

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The electrodiffusion is a non-linear transport process generated by two physical phenomena: diffusion and electrical activity of ions. The mathematical model is built up from the Poisson-Nernst-Planck (PNP) equations. Nowadays, the applications of this theory go of classic chemical and electrochemistry engineering, until technologies of the environment as desalination and alternative power as fuel batteries as well as biotechnology, biomedical engineering and micro-electro-mechanical



systems, among others. In this poster will be presented the numerical solutions of the PNP equations for some simplification cases on fuel cells. These numerical solutions were obtained from an iterative algorithm using the finite element method, with two and four ionic species interacting in a fuel cell.

### **11.3 Avances Sobre el Problema Inverso de la Tomografía de Capacitancia Eléctrica**

**Felix Augusto Aquino Camacho<sup>1</sup>, José Jacobo Oliveros Oliveros**

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En este trabajo se presenta una revisión de los avances en diferentes líneas de investigación sobre el problema inverso de la tomografía de capacitancia eléctrica así como el planteamiento general del problema haciendo énfasis en las dificultades teóricas y numéricas que se presentan.

### **11.4 Control System of Vertical Posture Dynamic Simulator**

**M. Reyes Romero<sup>1</sup>, W.F. Guerrero Sánchez<sup>1</sup>, V.V. Alexandrov<sup>1,2</sup>, T.B. Alexandrova<sup>2</sup>, and G.Yu. Sidorenko<sup>2</sup>**

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The vestibular apparatus (semicircular canals and otolith organs) plays an important role in the control of human vertical posture, the semicircular canals are stimulated by angular accelerations to the head that is submitted and initiate appropriate postural reflexes to stabilize head, the otolith organs are stimulated by linear accelerations (including inclinations with respect to the vector of gravity) and are responsible for the reflexes that act to restore the normal position of the head with respect to the apparent vertical. Here we present the control system for a dynamic simulator of vertical posture. The aim of future development of this simulator is to evaluate the operation of vestibular prosthesis. We use the inverted pendulum to simulate the vertical human posture. The dynamic simulator consists of two imitators, a mobile mimic of vertical posture and a simulator of vestibular function which we defined as MEMS (Micro-Electro-Mechanical Systems) of vestibular function. The control system consists of: a) MEMS (Micro-Electro-Mechanical-Systems) with a mathematical model of vestibular function that is the definition of MEMS vestibular function, b) a stabilization algorithm to vertical position based on feedback control using artificial sensors: accelerometer and gyroscope signals, (analog to semicircular canals and otolith organs, respectively) and encoder (analog to

sensors in the muscles of the body), and c) a test strategy that simulate the natural oscillation of the center of mass of a person and the first stage of a fall through the synthesis of two self-oscillations with different limit cycles, derived from solving a maximum deviation problem for the mobile mimic of vertical posture.

### **11.5 Lower Bound for Robustness in a Quasi Random Rumor Spreading Scheme**

**Charles Drake Poole**

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Quasi randomized rumor spreading protocols are used to spread information across a network. Doerr-Huber- Levavi showed that a quasi random rumor spreading protocol is as robust as the randomized protocol. They estimate the time steps required for robustness on a complete graph and use this estimation for every spanning subgraph. It is easily demonstrable that the spread of information across a graph is not dependent only on the node count, but also the edge distribution. Through simulation we have shown there exists a subnetwork of a network with an average degree of connectivity exceeding 13% with other nodes that represents a the minimum spread in complexity, with only an increase in average rounds of 14%. Our results show there exists a lower bound than the one proposed for complexity with the given probability of transmission failure when connectivity is considered.

### **11.6 Identificación y Aproximación de Fuentes Bioeléctricas en el Cerebro Considerando una Geometría Simple de la Cabeza**

**José Julio Conde Mones, José Jacobo Oliveros Oliveros, María Monserrat Morín Castillo**

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El problema inverso electroencefalográfico (PIE) consiste en determinar la fuente de actividad bioeléctrica en el cerebro a partir de mediciones electroencefalográficas sobre el cuero cabelludo. Este es un problema inverso mal planteado ya que puede haber fuentes diferentes que produzca la misma medición y además pequeños errores en la medición, la fuente correspondiente se aleja de la fuente real.

La actividad de la fuente puede corresponder a tumores cerebrales, daño cerebral, enfermedades infecciosas, condiciones epilépticas, entre otros, que se reflejan en la medición del potencial o electroencefalograma (EEG) sobre el cuero cabelludo.

Considera a la cabeza como un medio conductor, compuesta por dos capas conductoras con conductividad constante y positiva en cada capa, el PIE se lleva a una

ecuación operacional que asocia las fuentes con las mediciones mediante un problema de ecuaciones diferenciales parciales con condiciones de contorno. El ortogonal del núcleo de este operador compacto son las funciones armónicas ortogonales a las constantes del espacio de las funciones cuadrado integrables, de esta forma se le hace corresponder a cada medición exacta la componente armónica de la fuente bioeléctrica ortogonal a las constantes.

En este trabajo se presenta un algoritmo para identificar la componente armónica de la fuente bioeléctrica, que es la divergencia del vector densidad de corriente impresa  $J_p$  concentrada en el volumen cerebral, para el caso de dos esferas concéntricas el cual es una aproximación más realista de la cabeza, además se presenta un algoritmo estable de identificación de la fuente para el caso de mediciones con error, el cual es programado en Matlab y validado por ejemplos sintéticos.

### 11.7 El Fenómeno de Gibbs y el Método de Filtrado de $\sigma$ - Factor de Lanczos

**J. Miguel Uribe**

coautores: **J. Jacobo Oliveros O., J. Alberto Escamilla R.**

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Dada una función  $f : \mathbb{R} \rightarrow \mathbb{R}$  periódica de período  $2\pi$ , con una discontinuidad de salto en el punto  $x_0$ , el fenómeno de Gibbs se presenta, al momento de calcular la  $n$ -ésima suma parcial de Fourier de  $f$ , representada por  $S_N f(x_0)$ , la gráfica de la suma muestra una protuberancia cercana al punto de discontinuidad  $x_0$ , además para cualquier valor de  $n$  en la suma esta anomalía no deja de ocurrir, se demuestra que la diferencia entre el valor de la función  $f$  y de  $S_N f(x_0)$  es aproximadamente un 9% con respecto a la longitud de salto, esto se observará en la función escalonada de longitud 2. Además se exhibe el método del  $\sigma$  - factor Lanczos como método de filtrado, éste no elimina el fenómeno, sin embargo lo atenúa.

### 11.8 A Stable Algorithm for Recovering Bioelectrical Sources Represented by Dipoles

**María Monserrat Morín Castillo<sup>1</sup>, José Jacobo Oliveros Oliveros, Gabriela Morales Timal, Moisés Gutiérrez Arias**

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The problem of recovering the bioelectrical sources on the cerebral volume, from measurement of the potential generated by these sources on the scalp, known as Electroencephalogram, is called Inverse Electroencephalographic Problem (IEP). The forward problem consists on determining the electrostatic potential assuming that the bioelectrical source is known. The Electroencephalogram (EEG) is a valuable clinical tool for the study of the epilepsy and in this case the source is

represented by finite number of dipoles. One Green function and a model of conductive medium are used to establish relationships between the source and the EEG. For the experimental validation of the forward problem a physical system is building which consists in one electrical dipole inside of a conductive spherical medium and electrodes located on the surface of the spherical medium and the theoretical and experimental potentials are compared. Using the least square technique the IEP is reduced to a problem of parameter identification in finite dimension. In this work a stable algorithm is presented in order to find the parameter of the dipole using the theoretical and experimental data obtained from the physical system.

### 11.9 Diseño de un Control Óptimo Discreto para un Robot Móvil

**Gelacio Salas Ortega, M. Monserrat Morín Castillo, J. Eligió Moisés  
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En este trabajo presentamos la síntesis de un algoritmo de control para la estabilización de un robot móvil autónomo, partiendo de su modelo dinámico y de la trayectoria que deseamos que recorra. Se consideran algunos conceptos matemáticos importantes de la teoría de optimización para el planteamiento del problema de control optimal. En la práctica, un problema de optimización es aquél en donde se desea conducir la solución del sistema a un estado objetivo  $y_d$  y para ello se minimiza la distancia entre el estado inicial  $y$  e  $y_d$ . Así, con este planteamiento, nuestro problema de control, se reduce al cálculo de puntos extremos con restricciones.

La solución al problema de optimización planteado se encuentra mediante el principio discreto del mínimo y la programación dinámica, esto nos lleva a resolver una ecuación diferencial matricial del tipo Riccati y de esta manera se obtiene la ley de control optimal.

### 11.10 Composition of Physical Quantities that Fulfill Group Properties

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<sup>1</sup>Departamento de Física

<sup>2</sup>Departamento de Matemáticas

Any differentiable group law in an open interval of real numbers is isomorphic to the group of real numbers under addition. The outline of the proof will be presented. Emphasis will be given to the implications of this proposition in diverse physical formulae. Two approaches, suitable for different applications, will be undertaken: given the groups, to find the isomorphism between them, or given the isomorphism,

find the binary operation that they obey. Physical examples treated under this formalism yield well known results such as the relationship between entropy and number of micro-states or the relativistic composition of velocities in one dimension. Some less common but interesting composition rules will also be presented.

### **11.11 Natural Convection in a Square Cavity with Participating Medium**

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The natural convective flow in a two dimensional square cavity filled with a material which has properties of an optical participating medium is theoretically analyzed. Radiant energy coming from an external heat source is assumed to fall on a small region of one of the lateral walls of the cavity, and as the working fluid is assumed to be participating, the incoming energy is absorbed in its volume, heating the material by conduction, convection and radiation. The simultaneous presence of temperature gradients and a body force generates a convective motion. We present a mathematical model for describing this phenomenon which includes the conservation equations of mass, momentum and energy. The integral term that describes the radiation heat transport is included in the energy conservation equation. The solution is obtained with a numerical method and representative cases are described. This study has potential applications in the design of heat exchangers in central solar towers.

### **11.12 Numerical Simulations of Two Dimensional Bubbles**

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We present a numerical study of the dynamics of two dimensional individual bubbles ascending under the influence of buoyancy. First, we establish the physical and mathematical models that comprises the mass and momentum conservation equations for a system that includes a surrounding fluid and an individual bubble. We consider that the boundary of the bubble can be modified due to the external forces generated by the flow. The conservation equations are discretized with the finite volume method and the discontinuities at the interface of the fluids are treated with a front tracking technique. Finally, we discuss the dynamics of the bubbles by calculating the trajectory of the centroid, the time-dependent shape of the bubbles and the external flow generated by the passing of the bubble.

### 11.13 Two models for the simulation of pedestrian traffic

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Urban areas are generally very densely populated. With their continuing development, the result is higher concentrations of people in pedestrian facilities. This puts tremendous pressure on the pedestrian networks in these areas. Proper planning of pedestrian facilities is crucial to allow optimum performance. This is especially so when considering that pedestrian facilities are an integral part of the overall transportation network. This further increases the need to make pedestrian environments more attractive for walking, in terms of mobility, safety, efficiency, convenience as well as comfort.

For the reason above is necessary to understand the pedestrian flow that is why we will discuss two models to simulate pedestrian traffic: Social Forces and cellular automata. The social force model suggested that the motion of pedestrians can be described as if they would be subject to 'social forces'. These 'forces' are not directly exerted by the pedestrians' personal environment, but they are a measure for the internal motivations of the individuals to perform certain actions (movements).

The Cellular Automata Model simulates pedestrians as entities (automata) in cells. The walkway is modeled as grid cells and a pedestrian is represented as a circle that occupies a cell. The occupancy of a cell depends on localized neighborhood rules that are updated every time. Each pedestrian movement includes both lane changing and cell hopping. In each time step, each cell can take on one of two states: occupied and unoccupied.

Show that the models are able to mimic the behavior of crowd by computer simulations where we will build different types of scenarios to compare them.

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### 11.14 On the pensioner's management problem: A time consistent approach

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We consider a more general form of the Merton problem. The stock is as usual driven by

$$dS(t) = S(t)[\alpha dt + \sigma dW(t)], \quad 0 \leq t \leq \infty,$$

where  $\{W(t)\}_{t \in [0, \infty)}$  is a 1-dimensional Brownian motion on a filtered probability space  $(\Omega, \{F_t\}_{0 \leq t \leq \infty}, F, \mathbb{P})$ .

A decision-maker in this market is continuously investing his/her wealth in the stock/bond, is consuming and is buying life insurance. Moreover he/she is receiving income at the continuous deterministic rate  $i(t)$  at each point in time  $t$ .

An investment-consumption-insurance strategy is determined by the amount he/she invests in the bond/stock  $\zeta(t)$  at time  $t$ , the consumption rate  $c(t)$  and the insurance rate  $p(t)$ . Given a strategy process  $\{\zeta(t), c(t), p(t)\}_{t \in [0, \infty)}$ , the equation describing the dynamics of wealth  $X^{\zeta, c, p}(t)$  is given by

$$dX^{\zeta, c, p}(t) = rX^{\zeta, c, p}(t)dt - c(t)dt - p(t)dt + i(t)dt + \zeta(t)(\alpha dt + \sigma dW(t)) \quad (0.1)$$

The above equation is usually referred to as the self-financing condition. The initial wealth  $X^{\zeta, c, p}(0) = X(0) \in (0, \infty)$ , is exogenously specified.

The time horizon is fixed (e.g.  $T=65$  years) and the death rate at time  $t$  is  $\lambda(t)$ .

If the decision-maker dies at time  $t$ ,  $0 < t \leq T$ , then his/her family will get the insurance amount  $l(t)p(t)$ . Thus decision-maker legacy when he/she dies at time  $t$  is wealth plus insurance amount, i.e.,

$$Z(t) = \eta(t)X(t) + l(t)p(t). \quad (0.2)$$

Although the insurance premium  $p(t)$  is allowed to be negative we require that the legacy  $Z(t)$  stays positive.

At all times the decision-maker has the same von Neuman-Morgenstern power utility  $U(x) = U_\gamma(x) = \frac{x^\gamma}{\gamma}$ , for intertemporal consumption and  $\bar{U}(x) = nU_\gamma(x)$  for final wealth.

When it comes to his/her legacy we assume that the family has the same von Neuman-Morgenstern power utility  $U(x) = U_\gamma(x)$ , but when measure it the decision-maker weights by a deterministic time varying Pareto weight  $m(t)$ .

In order to evaluate the performance of an investment-consumption-insurance strategy the decision maker uses an expected utility criterion; for an admissible strategy process (and under certain technical assumptions)  $\{\zeta(s), c(s), p(s)\}_{s \in [0, \infty)}$  and its corresponding wealth process  $\{X^{\zeta, c, p}(s)\}_{s \in [0, \infty]}$  (see (0.1)) we denote the expected utility functional by

$$J(t, x, \zeta, c, p) \triangleq \mathbb{E} \left[ \int_t^{T \wedge \tau} h(s-t) U_\zeta(c(s)) ds + nh(T-t) U_\zeta(X^{\zeta, c, p}(T)) 1_{\{\tau > T | \tau > t\}} \right. \\ \left. + m(\tau-t) \hat{h}(\tau-t) U_\zeta(X^{\zeta, c, p}(\tau)) 1_{\{\tau \leq T | \tau > t\}} \mid X^{\zeta, c, p}(t) = x \right], \quad (0.3)$$

where  $h, \hat{h}$  are discount functions.

We allow the insurance premium rate  $p(t)$  to be negative which means that the decision maker can sell life insurance. The value function  $v(t, x)$  is the maximum over all admissible strategies  $(\zeta, c, p)$  of  $J(t, x, \zeta, c, p)$ .

This gives rise to a HJB whose coefficients are time-dependent and therefore giving rise to time-inconsistency. We then introduce the notion of equilibrium.

More precisely,  $(\bar{\zeta}, \bar{c}, \bar{p})$  is an equilibrium policy iff  $\forall t \in [0, T]$  and  $\epsilon > 0$  sm

$$\liminf_{\epsilon \downarrow 0} \frac{J(t, x, \bar{\zeta}, \bar{c}, \bar{p}) - J(t, x, \zeta_\epsilon, c_\epsilon, p_\epsilon)}{\epsilon} \geq 0, \quad (0.4)$$

where  $(\zeta_\epsilon, c_\epsilon, p_\epsilon)_{s \in [t, T]}$  is a strategy coinciding with  $(\bar{\zeta}, \bar{c}, \bar{p})$  on  $[t + \epsilon, T]$  and arbitrary on  $[t, t + \epsilon]$ .

We show that we can give an explicit solution in the case of power utilities.

## 11.15 Non Hermitian Operators and Quantum Finance

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We study non-Hermitian operators acting in Hilbert space  $L^2(\mathbb{R}^3)$ . By the operator  $PT(f(\vec{x})) = f^*(-\vec{x})$ . We define a new scalar product in  $L^2(\mathbb{R}^3)$ . It shows that various differential equations can be written in terms of these operators, in particular the Black-Scholes equation

$$\frac{\partial C}{\partial t} = -\frac{\sigma^2 S^2}{2} \frac{\partial^2 C}{\partial S^2} - rS \frac{\partial C}{\partial S} + rC,$$

which is used to model investments in mathematical finance. We also show that this equation can be transformed into a Schrödinger equation type. We study other applications of these operators in areas such as supersymmetric quantum mechanics.

References

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## 11.16 High Performance Computing Applied to Numerical Solution of Coupled Problems

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While numerical methods for single-field problems have reached a high degree of maturity, computational methods for coupled problems have been far less developed, due to the major qualitative differences between different physical phenomena, applying a uniform computational approach is virtually impossible.

For understanding and simulating the behavior of coupled-field it is necessary to analyze several physical domains as, e.g., temperature, velocity, pressure, electric field, magnetic field, etc. The coupling between domains can be caused by imposed boundary conditions or when there is a superposition of different domains.

Analytical solutions for coupled-field problems are hard to be obtained and numerical modeling tools are needed as, e.g., Finite Element Method. However, given the complexity of such problems, many computational resources are needed to solve them and it is necessary to use advanced computational techniques as, e.g. MPI (communication between processors), METIS (mesh partitioning), MUMPS (Multifrontal Massively Parallel sparse direct Solver), etc. In this work attention is given to apply this techniques to the solution of the following coupled problems: fluid-structure, thermalfluid, and electromechanical.

To solve these problems we use scientific computing field tools widely recognized as GiD (pre-processor and post-processor), Kratos, and getfem++ (Finite Element Method Frameworks). The Finite Element Method is used for the numerical modeling and its implementation is done in an object oriented code written in C++.

This work has described our first efforts towards the construction of a Hight Computing Performance-based numerical tool for simulating coupled-field problems. It is of great importance to reduce the execution times so that we can explore the models most widely. Our simulation techniques solve these kind of problems in considerably less time in comparison with traditional techniques, allows us to further analyze the model and therefore, get results closer to reality.

## 11.17 To Be Announced

**F. Benítez**

This research work is the first attempt to systematically develop a general theory of initial and boundary value problems for evolutive nonlinear equations of the type:

$$u_t + \mathbb{N}(u) + \mathbb{K}(u) = 0,$$

where  $u = u(x, t)$ . The non linear term  $N(u)$  depends on a unknown function  $u$  and its derivate  $u_x$  as:

$$N(u) = \sum_{\alpha, \beta} C_{\alpha\beta} u^\alpha u_x^\beta, \quad \alpha, \beta > 0$$

The lineal operator  $K(u)$  is described by the following polynomial:

$$K(u) = \sum_{i=1}^m a_i u_x^{(i)}.$$

Many problems that appear in physics, engineering and other sciences are described by equations in partial derivatives whose solutions describe wave behavior. To calculate a numerical solution it is necessary, due to a finite computational capacity, to truncate the non delimited definition domain where the problem is originally posed. This is carried out by introducing an artificial boundary which defines a new integration domain. In order to set out the problem properly, this new domain must be closed with a suitable boundary condition in such a way that the boundary condition coincides with the proposed problem.

The analytical study of the basic properties of the proposed non linear problem solution can permit adjustment and optimization of the numerical programs for computing experiments, prediction of explosive phenomena and smoothing effects of solutions, and finding the sufficient conditions for global existence.

The asymptotic methods theory is complex in linear equations and even more in non linear equations where is necessary to demonstrate the global existence of the solutions, to obtain additional estimations in order to understand these solutions better and to individually study each type of non linearity. Despite the importance and the topicality of the asymptotic methods there are relatively few results for the non linear equations not only for initial value and boundary problems, but also in the case of the Cauchy problem (for any  $x$  without considering boundaries).

In this work an analytical development to obtain the solution for the proposed non linear problem is presented. This is carried out by means of the Green function construction methodology. Such analysis permits knowing how many boundary values are needed to find a unique solution. By using advanced mathematical tools, some estimations are performed to find the asymptotic behavior of the Green function and finally to obtain the solution for the non linear problem. Additionally, some industrial or engineering applications are presented where the developed analytic method can be used.

### 11.18 Mathematical Properties of Wavelet Filters Used in Ultrasound and Mammography Images for Different Applications

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In previous works we have carried out analysis of different Wavelets used especially for Ultrasound (US) and Mammography (MG) images compression, included new Wavelets families based on atomic functions. This way we have been able to determine that type of filters Wavelet works better for a specialized processing scheme for this type of images. Here, we determine and compare their key properties: Frequency response, Approximation Order, Projection cosine, and Riesz bounds, these properties key was obtained for the classic Wavelets W9/7, Daubechies8 and Symlet8, as well as for the complex Kravchenko-Rvachev wavelets  $\psi(t)$  based on the Atomic Functions  $up(t)$ ,  $fup^2(t)$ , and  $eup(t)$ .

With sensors and computers becoming more powerful, scientists are collecting and analyzing data over an ever-increasing speed. In many fields, such as astronomy, medical imaging, and computer vision, the data volume is very large. This data should be compressed to optimize the storage devices.

In this work, we investigate Wavelet-based techniques for compression and pattern recognition, focusing on different Wavelets based in Atomic Functions. The main idea behind these techniques is to use Wavelets to transform data set into a different basis, where the non important information can be eliminated.

Using the key properties of the different Wavelets used we can justify the obtained experimental results for compression and pattern recognition of US and MG images.

### 11.19 Validación Numérica y Experimental de un Algoritmo de Identificación de Fuentes Bioléctricas de Tipo Polar

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En la medicina existen métodos para el diagnóstico de enfermedades en el cerebro, actualmente se investigan nuevas formas de diagnóstico basadas en métodos no invasivos un ejemplo de esto es la electroencefalografía (EEG). Esta técnica se utiliza en la investigación del cerebro porque se considera de bajo costo y es de fácil acceso a la información, basta colocar electrodos sobre el cuero cabelludo para detectar potencial proveniente de la actividad eléctrica del cerebro.

En este trabajo se presenta un problema de identificación de fuentes en el cerebro utilizando la técnica del (EEG), el cual consiste en determinar fuentes bioeléctricas a través del potencial que producen, por medio de un modelo de medio conductor se obtiene un problema de valores en la frontera que permite el análisis de existencia y unicidad de este problema de identificación. Se presenta también el análisis del problema directo e inverso electroencefalográfico para el caso correspondiente a una fuente de tipo dipolar, así como el planteamiento de un problema de minimización para recuperar los parámetros de la fuente por medio de las mediciones para el caso del problema inverso. Debido al mal planteamiento de este problema es necesario aplicar un método de regularización como Tikhonov el cual permite identificar de manera estable estos parámetros.

Para la validación experimental se construye un sistema físico el cual consiste en colocar un dipolo eléctrico dentro de una esfera conductora, lo que simulara a una fuente dipolar en el interior de la cabeza. Las mediciones de potencial producidas por el dipolo se registran a través de electrodos los cuales se colocan en la superficie de la esfera.

Palabras clave: EEG, modelo de medio conductor, problema directo, problema inverso, dipolo eléctrico, método de mínimos cuadrados, método de regularización de Tikhonov.

### **11.20 Diseño de Leyes de Control por Retroalimentación de Salida para la Alineación de la Antena de un Satélite con la Antena de la Estación en Tierra**

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El presente trabajo aborda el desarrollo de leyes de control no lineales aplicadas al movimiento angular de un satélite. El objetivo consiste en alinear la antena de comunicación del satélite con la antena de la base terrestre. Para esto, dos leyes de control son propuestas; la primera considera que el vector de velocidad angular es disponible, así como un vector de dirección de la antena de la estación en tierra expresado en el sistema de referencia del satélite, el cual tienen como origen el centro de masa del mismo. La segunda ley de control solo considera al vector de dirección de la antena de la estación en tierra expresado en el sistema de referencia del satélite y el efecto de amortiguamiento introducido por el vector de velocidad angular es remplazado por un sistema dinámico virtual construido por el vector antes mencionado y su derivada filtrada. Esto es lo que se le conoce como un esquema de retroalimentación de salida con inyección dinámica. Desde un punto de vista práctico, la ventaja y originalidad del esquema propuesto es el de utilizar el menor número de sensores posibles, sin degradar el desempeño de la estabilización. Por medio de un análisis basado en el formalismo de Lyapunov se demuestra que las

leyes de control estabilizan al sistema de manera asintótica y global. Simulaciones computacionales corroboran el desempeño del sistema en lazo cerrado y muestran su robustez con respecto a incertidumbre en el conocimiento de los parámetros y con respecto a ruido en las medidas.

### 11.21 Application to Inverse Problems for Partial Differential Equations

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Informally, we may say that inverse problems are concerned with determining causes for a desired or an observed effect. Such inverse problems more often do not fulfill Hadamard's postulates of well-posedness, i.e. they might not have solution in the strict sense, solutions might not be unique and/or might not depend continuously on the data. Mathematical problems having these undesirable properties are called *ill-posed problems* and pose severe numerical difficulties, because of the discontinuous dependence of solutions on the data.

*Regularization methods* are used to deal with ill-posed problems, mainly to restore stability of the solutions with respect to data. The goal of this work is to illustrate the ill-posedness and the regularization methods for a linear inverse problem for partial differential equation in 1-D and 2-D, called usually as the problem with inverse time direction.

### 11.22 Diseño de un Mini Sistema de Aeronavegación Basado en Sensores de Tecnología MEMS y GPS

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El presente trabajo consiste en el diseño e implementación de un mini sistema de aeronavegación, que provee todas las variables necesarias para el control y estabilización de mini vehículos aéreos no tripulados; posición lineal, velocidad lineal, velocidad angular y orientación. El sistema está compuesto de dos subsistemas para dotar de flexibilidad al usuario. El primero permite estimar la velocidad angular y la orientación en tiempo real. Mientras que el segundo permite obtener también la posición y velocidad lineal gracias a la adición de señales GPS. Todos los sensores son de tecnología MEMS por lo que el sistema resultante tiene un peso de 350 gramos. La información es entregada a una computadora vía USB a una frecuencia de 80 Hz. El sistema propuesto puede ser utilizado por cualquier aeronave de

dimensiones reducidas (aviones, helicópteros, dirigibles) aunque por sus características, éste puede ser también utilizado en naves aéreas tripuladas y en aplicaciones terrestres. La contribución científica del trabajo, consiste en la elaboración del algoritmo de fusión de datos provenientes de los diferentes tipos de sensores, tomando en cuenta la característica del ruido y la frecuencia de muestreo de cada uno de ellos. Para ello se implementó un Filtro de Kalman Extendido (EKF), conjuntamente con un algoritmo de optimización. Exhaustivas pruebas en simulación y en tiempo real muestran la eficiencia de los algoritmos propuestos.

En México no existe investigación dirigida al desarrollo y la aplicación de nuevos y avanzados sistemas de estimación de orientación y posición, por lo que este trabajo es uno de los pioneros en esta área del conocimiento y desarrollo y donde grandes esfuerzos deben realizarse para aprovechar las grandes oportunidades que esto ofrece y comenzar a desarrollar tecnología mexicana.

### **11.23 El Primer Teorema Fundamental de Valuación de Activos**

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El estudio de los mercados financieros ha cobrado gran interés por parte de los matemáticos durante las últimas cuatro décadas. La administración de portafolios, el manejo del riesgo, la valuación de derivados financieros y los modelos de tasas de interés son los tópicos que se abordan de manera regular en las finanzas matemáticas.

En este trabajo comentamos una versión del principio de no-arbitraje, que permite formular el Primer Teorema Fundamental para la Valuación de Activos en tiempo discreto y horizonte finito. Este teorema es una pieza clave en la valuación de derivados financieros, y está presente en el funcionamiento de las principales bolsas de valores del mundo.

### **11.24 Recycling data for efficient numerical interpolation-based model order reduction**

**Aarón De La Concha G.**

Current Model Order Reduction Techniques can be gathered into two major groups. One of them, Truncation Methods using Singular Value Decomposition (SVD) procedures to select the important parts of the system and neglecting the rest. On the other hand Krylov-Interpolation methods, often refer as Moment Matching techniques. The main idea of them, is to match as many as possible moments of both original and reduced system transfer functions at certain points  $\sigma_j \in \mathbb{C}$ ,  $j = 1, 2, 3, \dots, n$ . Computing those moments explicitly leads to numerical instabilities, one way to overcome this problem is to impose Krylov-Subspaces moment matching conditions. For MIMO (Multiple Input Multiple Output) systems,

an algorithm called MIRIAM (MIMO Iterative Rational Interpolation Algorithm) was engineered to compute directly the reduced system out of the original one by imposing such conditions. We use this algorithm to explore an alternative route to accelerate the computations needed to build up the desired reduced system.

### **11.25 Segmentation and Face Detection**

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Face detection has been very handy for various image processing applications in real time, such as security surveillance, videoconferencing, tracking and people counting applications or for man-machine interface, to name a few.

Currently there is diversity among the techniques used in face detection, all effective and often very fast. We consider a learning method, one that can teach the machine what type of object you want to recognize and then have a technique to select and classify objects that you want to identify.

We provide an overview of several modules aimed to face detection: segmentation, machine learning and classification of selected images by using the Viola-Jones method.

### **11.26 Optimal control theory in vaccination**

**Sunmi Lee**

Arizona State University

The implementation of optimal control strategies involving vaccination measures can reduce significantly the number of clinical cases of influenza. The implementation of pandemic-level control measures must be carefully assessed specially in resource-limited situations. The 2009 A (H1N1) influenza pandemic was rather atypical. It began in North America at the start of the spring and in the following months, as it moved south, efforts to develop a vaccine that would mitigate the potential impact of a second wave were accelerated. The world's limited capacity to produce an adequate vaccine supply over just a few months resulted in the development of public health policies that had to optimize the utilization of limited vaccine supplies. Furthermore, even after the vaccine was in production, extensive delays in vaccine distribution were experienced for various reasons. In this talk, we use optimal control theory to explore the impact of some of the constraints faced by most nations in implementing a public health policy that tried to meet the challenges that come from having access only to a limited vaccine supply that is never 100% effective.

### 11.27 Proyecto de Cortabilidad de pieles en ItalModa

**Ricardo Romo Romero**

La presente trabajo trata sobre una aplicación de la Matemática en un problema real de optimización detectado en la empresa, **ItalModa S.A. de C.V.** donde por medio de dos modelos matemáticos se busca la optimización de los recursos humanos y materiales contribuyendo a la productividad, eficacia y eficiencia de la elaboración del calzado.

El primer modelo es el determinista que consiste principalmente en obtener una relación entre la calidad de piel y la cantidad de piel de cierta calidad, y el modelo o cantidad de piezas del calzado.

El segundo modelo es el estocástico, que aborda el problema tomando como variable aleatoria el trabajo del cortador, dando parámetros que indican si realizó un trabajo bueno o malo.

### 11.28 Modeling Metabolic Cooperation in a Public Goods Game

**Ayari Fuentes-Hernández**

The condition favouring cooperation is one of the central problems in evolutionary biology. Here we put forward a quantitative modelling approach for studying the evolution of cooperation incorporating aspects of the basic biochemistry and genetics of the biological system. We consider a microbial experimental system consisting of two strains of yeast. The first one, termed *producer* or *co-operator*, secretes the enzyme invertase which catalyses the hydrolysis of sucrose into fructose and glucose, the preferred carbon source of yeast. The second strain, termed *non-producer* or *cheat*, does not secrete invertase and as a consequence does not suffer the manufacturing costs but nonetheless reaps the reward by consuming glucose and fructose. We use prior data on the biochemistry of the two yeast strains to parametrise the mathematical model and make numerous predictions regarding fitness of invertase producers and non-producers under a variety of spatially structured experimental environments. Theory often considers that the best for a group is that everyone co-operates, however we found that population growths is maximal when both types coexist.

### 11.29 Medición y Administración de Riesgo Operacional con Redes Bayesianas

**José Francisco Martínez Sánchez**

Instituto Politécnico Nacional

**Objetivo:** Implantar una Red Bayesiana para valorar y administrar el Riesgo Operacional<sup>3</sup> en el Mercado de Dinero (MD) del sector financiero en México.

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<sup>3</sup>Riesgo Operacional se define como: el riesgo de pérdida resultante de la insuficiencia o fallas de procesos, personas y sistemas o de eventos externos.



**Antecedentes:** El riesgo operacional se ha convertido en un área de creciente preocupación en el sector financiero. El aumento de la sofisticación y complejidad de las prácticas bancarias ha incrementado tanto de las entidades reguladoras como de la industria la conciencia de los riesgos operativos y sistemas de medición. Desde el momento de la liberación del segundo documento consultivo en el Nuevo Acuerdo de Capital en 2001, el Comité de Basilea de Supervisión Bancaria estableció un tratamiento específico para el riesgo operacional: un componente básico del nuevo marco está representado por el Pilar 1, que pide explícitamente un mínimo de capital para esta categoría de riesgo.

**Problemática:** En recientes décadas se han presentado cambios que impactaron al sector bancario, entre los que destacan:

**Desregulación.** Empieza en los 70's a partir de que el acuerdo de Bretton Woods queda obsoleto, en los 80's los mercados de dinero y de capitales se desregulan. El papel comercial y las notas de mediano plazo aparecen en los mercados financieros motivando la intermediación de instituciones financieras, se introducen los derivados como mecanismo para administrar riesgos; sin embargo, también se utilizan para especular.

**Globalidad.** Se abren las puertas a la competencia del exterior lo que implica programas de reducción de costos que pueden poner en riesgo la operación del sector; también los subsidios cruzados resultan un peligro para las instituciones. Un aspecto fundamental es la cultura e idiosincrasia del país o región, algunas políticas pueden ser exitosas en Europa pero no en Latinoamérica. La operación de los bancos transnacionales se ven afectadas, debido a que existen procesos que son en línea y otros que se ejecutan de manera global en zonas horarias distintas, lo que genera un riesgo alto de operación.

**Productos más complejos.** Debido a la introducción de derivados los productos financieros se vuelven más complejos para identificar y analizar los riesgos inherentes. La complejidad también se presenta en los sistemas de información, los cuales no se desarrollan a la velocidad de los productos derivados.

**Internet como canal de distribución.** Hoy en día internet es utilizado en casi todos los campos y áreas de la actividad humana, incluyendo las actividades criminales. En el caso bancario, los servicios en línea abren sus sistemas y aún con las medidas de seguridad quedan huecos que son aprovechados para obtener beneficios ilegales. Como ejemplos de actividades ilegales tenemos: la clonación de tarjetas, la ingeniería social, phishing, spyware, software malicioso, entre otros.

El sector financiero proporciona sus servicios en todas las líneas y procesos de negocio soportados en tecnologías de información; incluyendo: sistemas, bases de datos, telecomunicaciones, servidores, computadoras, software comercial, software libre, protocolos de comunicaciones, protocolos de seguridad, entre otros. El grado de interrelación es tan grande, que prácticamente sería imposible el funcionamiento del sector bancario sin las tecnologías de información.

La cultura del riesgo y en especial del operacional no ha tenido la importancia requerida, el sector financiero se preocupa más por atender los vaivenes del mercado y las posibilidades de incumplimiento para el caso de los créditos; sin embargo, los eventos de riesgo operacional han demostrado su capacidad devastadora en instituciones del sector.

Los esfuerzos del sector bancario en la evaluación y administración del riesgo operacional están encaminados fundamentalmente a cumplir con la normatividad en la materia, sin embargo; las pérdidas en la última década y en el peor de los escenarios la quiebra de personas y empresas obliga a realizar estudios más profundos sobre las causas y efectos del riesgo operacional en el sector bancario.

En este sentido, el presente trabajo analiza desde un contexto integral las causas y efectos involucrados en los eventos de riesgo operacional, no sólo desde una lógica cuantitativa, sino que se incluyen elementos subjetivos que en conjunto con los datos “duros” se generan modelos consistentes de riesgo operacional; para este análisis se toma como base la Teoría de las Redes Bayesianas (modelos causales). En específico se estudia el Mercado de Dinero, debido a la importancia que tiene este segmento en el financiamiento de corto plazo del gobierno y las empresas.

**Metodología:** Se analizarán los fundamentos del enfoque Bayesiano para construir una red que involucra datos internos (estadísticos), datos externos (opinión de expertos), análisis de escenarios y control del entorno.

Con el modelo propuesto se calculará el riesgo operacional del Mercado de Dinero en INDEVAL y se comparará con los resultados generados por modelos estrictamente estadísticos, esperando obtener mejores resultados con el enfoque bayesiano.

### 11.30 Solution of the Heat Equation with the Method of Multiple Scales

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We going to examine the problem of heat flow over a uniform one-dimensional cylindrical rod of length  $L$  and in this problem there are no sources of heat energy. The equation of the heat flow is given by

$$c\rho\frac{\delta u}{\delta t} = K_0\frac{\delta^2 u}{\delta x^2} \quad (2.4)$$

where  $u$  is the temperature,  $t$  the time,  $x$  measure the distance along the rod,  $c$  the specific heat,  $\rho$  the mass density and  $K_0$  the thermal conductivity.

We use the Multiple Scale method to solve this problem adding initial and boundary conditions. Initially there is a uniform temperature of zero in the rod, we require the rod be insulated, that is, there is not flux trough this end, and we specify the heat flux to be some know function and then we vary the heat flux slowly.

The Multiple Scale method is used to solve this Partial Differential Equation (PDE), but we reduce the problem to an ODE using separation of variables techniques.

### **11.31 A Model to Show That The Maximum Earthquake Size Increases With Increasing Convergence Rate and Decreasing Lithospheric Age**

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The Olami, Feder and Christensen (OFC) model is a non-conservative two-dimensional version of the Burridge and Knopoff (BK) spring-block model used to simulate the behavior of a seismic fault. The model is mapped in a cellular automaton, which is described by a quite simple algorithm. Every time the algorithm is repeated we obtain a synthetic earthquake with its magnitude, epicenter and duration time. When we repeat this algorithm a lot of times we obtain a catalogue of synthetic earthquakes, which we can represent as a time series. Such series exhibit power law behavior so much for the magnitudes (Gutenberg-Richter law) as for the duration times, the model has other properties that are related to real seismicity. In this work we also describe how we can modify the basic OFC model in order to demonstrate the existence of correlations between the nature of seismic energy release and the physical characteristics of subduction zones. In general, we can show with the model that total seismic energy release rates are highest along subduction zones where young oceanic crust is subducted rapidly and that the maximum observed earthquake size increases with increasing convergence rate and decreasing lithospheric age. These facts are observed in real seismicity.

### **11.32 A Method for Segmentation of Ultrasound Images with Intensity Inhomogeneity Correction**

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B-mode ultrasound imaging is one the most frequently used diagnostic tools in clinical applications, because there is a low health risk to the patient and the cost of scan is low relative to the cost of other imaging modalities. In particular for breast cancer detection an alternative to the mammography is ultrasound imaging. However, ultrasound images often exhibit tissue intensity inhomogeneities dominated by nonuniform beam attenuation within the body. This is the major problem for intensity-based segmentation. In this work, we present a method proposed by Xiao et al. to process (image enhancement and segmentation) B-mode ultrasound images. This method uses a combination of the maximum a posteriori (MAP) and Markov random field (MRF) methods to estimate the US image distortion field assuming it follows a multiplicative model while at the same time labeling image regions based on the corrected intensity statistics. The MAP step is used to estimate the intensity model parameters while the MRF step provides a way of incorporating the distributions of image tissue classes as a spatial smoothness constraint. This

method is applied to a series of images to test the accuracy of the approach and on clinical breast data sets to show potential clinical utility.

### 11.33 An Elementary Characterization of Low Order Matrix Exponential Distributions

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A continuous probability distribution with density function  $f$  is said to belong to the class of *matrix exponential distributions* (ME) if its Laplace transform  $Lf(s)$  is a rational function of  $s$ . In this poster we address the following problem: *characterize  $L(ME)$ ; that is to say, give necessary and sufficient conditions for a rational function  $\Phi(s)$  to be the Laplace transform of an ME distribution.* Suppose  $\Phi(s) = p(s)/q(s)$  is a quotient of relative prime polynomials  $p$  and  $q$  with  $\deg p < \deg q$ . Using elementary methods we present a complete solution in terms of  $p$  and  $q$  when  $\deg q \leq 3$  and significant progress when  $\deg q = 4$ . Then we compare our results with those of M. Fackrell, et al., who give a complete characterization of  $L(ME)$  in terms of certain convex sets when  $\deg q \leq 3$ . This work has been done under the supervision of Professor M. Bladt from IIMAS-UNAM.

### 11.34 Persistence, Extinction and Invasion of an Epimedic in a Population

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This work deals with the problem of persistence, extinction and invasion of an epidemic in a population through a standard model in epidemiology, like the SIRS model. Considering two incidence rates: the classical rate and the LHD rate, taken of [1]. We explored the predictive capabilities of the SIRS model with these incidence rates deterministically and stochastically.

#### *References*

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### 11.35 Parameters estimation for a SIR epidemiological model with spatial adaptation to the metropolitan zone of Guadalajara

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In this work we used a space adaptation of a SIR epidemiological model to describe the propagation of the influenza AH1N1 virus on the metropolitan zone of Guadalajara.

To study the spread disease, we need estimate the model's parameters, to know the basic reproductive number  $R_0$  of the system, using the maximum likelihood parameters estimation in dynamical systems and cubic interpolation.

### 11.36 Modelado, Diseño e Implementación de un mini vehículo aéreo PVTOL con fines didácticos y de investigación

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En la última década, la investigación en vehículos aéreos no tripulados, se ha concentrado principalmente en los vehículos con capacidad de despegue y aterrizaje vertical VTOL (del inglés Vertical Take-Off and Landing). Esto es debido a su capacidad para realizar vuelos estacionarios, así como la gran movilidad, características importantes y necesarias en una gran cantidad de aplicaciones, como la supervisión de infraestructuras, acciones de desastre y protección civil, supervisión de tráfico, entre otras. Cuando se considera que un vehículo VTOL evoluciona solamente en el plano vertical, el sistema resultante es conocido como sistema PVTOL (Planar Vertical Takeoff and Landing). El PVTOL es un sistema no lineal de fase no mínima (i.e. Sistema no lineal con dinámica cero que no es asintóticamente estable) lo que hace de este sistema un verdadero desafío para la comunidad de control.

Este trabajo presenta el modelado, diseño, implementación y control de un prototipo PVTOL, el cual es utilizado para fines de enseñanza e investigación. El diseño mecánico se realizó utilizando un software especializado, permitiendo optimizar dimensiones y peso. De esta manera, la estructura del PVTOL se realizó a base de fibra de carbono, lo cual lo hace fuerte y ligero. El sistema de propulsión se implementó con dos hélices acopladas a motores de corriente directa. El sistema sensorial se basa en sensores de tecnología MEMS (acelerómetros y girómetros). El

algoritmo de control es implementado en una PC. La interface entre el sistema y la PC se hace vía USB por medio de una tarjeta de adquisición de datos. Este sistema de laboratorio permite probar de una forma rápida y segura, diferentes algoritmos de control. Así mismo le permite al estudiante, tener un acercamiento rápido a la modelación matemática, a la aeronáutica, al control lineal y no lineal y a la teoría de problemas inversos. Cabe mencionar que este sistema se llevo a cabo en el marco del verano científico, donde diferentes jóvenes de la republica colaboraron en este proyecto.

### **11.37 To Be Announced**

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In this paper we discuss the properties of fuzzy random variables with new meter and some extended results of monotone convergence theorem and dominated convergence theorem for fuzzy random variables. The main result is given by using  $D_{p,q}$ -distance defined on the set of fuzzy numbers.

### **11.38 On the Asymptotic Properties of the ARX Models in Adaptive Tracking**

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Some asymptotical results for vector ARX models in the reference trajectory tracking with unknown parameter framework are presented, such results include the almost sure convergence of the Least Squares and Weighted Least Squares algorithms together with a Central Limit Theorem and a Law of Iterated Logarithm for the same estimation algorithms. In addition some results around the Almost Sure Central Limit Theorem for vector martingales applied to the moment estimation of the noise associated with the ARX model are also provided.

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