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Invited Speakers

Jalal Abedi, University of Calgary, Canada
Yann Brenier, Nice, France
Alexandre Caboussat, University of Houston, U.S.A.
Suncica Canic, University of Houston, U.S.A.
Zhangxin (John) Chen, University of Calgary, Canada
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Place of the Conference: Main Building B--103

Program

July 9, 2008 (Wednesday) **Room: Main building B--103**

8:30 ~ 9:00	**Opening Ceremony and Taking Pictures (Chair: Zhangxin Chen)**
	Session 1 (Chair: Yanren Hou)
9:15 ~ 10:00 **Roland Glowinski** University of Houston, U.S.A. **Title: Computation of the best constant in some Strauss-Nirenberg inequalities**	
10:00 ~ 10:30	**Coffee Break**
	Session 2 (Chair: Jiwen He)
10:30 ~ 11:15 **Ta-Tsien Li** Fudan University, China **Title: Mechanism of the formation of singularities for quasilinear hyperbolic systems**	
11:15 ~ 12:00 **Zhangxin Chen** University of Calgary and Southern Methodist University, Canada **Title: Beyond CSS, SAGD, and VAPEX: Reservoir Modeling and Simulation for Heavy Oil and Oil Sands**	
12:00 ~ 14:00	**Lunch**
	Session 3 (Chair: Lihe Wang)
14:00 ~ 14:45 **Kaitai Li** Xi'an Jiaotong University, China **Title: Boundary Shape Control of Navier-Stokes Equations and A Dimensional Splitting Method for 3D Navier-Stokes Equations**	
14:45 ~ 15:30 **Ronald H.W. Hoppe** University of Houston, U.S.A. **Title: Convergence Analysis of an Adaptive Interior Penalty Discontinuous Galerkin Method**	
15:30 ~ 16:00	**Coffee Break**

July 9, 2008 (Wednesday) **Room: Main building B--103**

Session 4 (Chair: Jacques Rappaz)
16:00 ~ 16:45 **Alexandre Caboussat** University of Houston, U.S.A. **Title: Numerical Solution of Non-Smooth Advection-Diffusion Problems Arising in Sand Mechanics**
17:05 ~ 17:25 **Heyuan Wang** Liaoning University of Technology, China **Title: The Dynamical Behavior and the Numerical Simulation of a Five-Modes Lorenz System of the MHD Equations For a Two-Dimensional Incompressible Fluid on a Torus**
17:25 ~ 17:45 **Kui Ren** University of Chicago, U.S.A. **Title: Transport equation for acoustic waves in discrete random media**

July 10, 2007 (Thursday) **Room: Main building B--103**

Session 5 (Chair: Penger Tong)	
8:30 ~ 9:15 **Jacques Rappaz** Institute of Analysis and Scientific Computing, EPFL, Switzerland **Title: Scientific computing for aluminum production**	
9:15 ~ 10:00 **Xiaobing Feng** The University of Tennessee, U.S.A. **Title: Numerical Methods for Semigeostrophic Flows: A Fully Nonlinear Approach**	
10:00 ~ 10:30	**Coffee Break**
Session 6 (Chair: Ronald H.W. Hoppe)	
10:30 ~ 11:15 **Jiwen He** University of Houston, U.S.A. **Title: Phase and Chemical Equilibrium Computation in Air Quality Modeling**	

July 10, 2007 (Thursday) **Room: Main building B--103**

11:15 ~ 12:00 **Ping Lin** University of Dundee, Scotland, U.K. **Title: Computational Methods for Molecule Orientations of Liquid Crystals and Liquid Crystal Flows**	
12:00 ~ 14:00	**Lunch**
Session 7 (Chair: Ping Lin)	
14:00 ~ 14:45 **Penger Tong** The Hong Kong University of Science & Technology, HongKong **Title: Pattern Formation in a Rotating Suspension of non-Brownian particles**	
14:45 ~ 15:05 **Zhiming Gao** Xi'an Jiaotong Universtiy, China **Title: Adjoint Methods for Shape Optimization for the Viscous Incompressible Flow**	
15:05 ~ 15:25 **Xinfeng Liu** University of California at Irvine, U.S.A. **Title: Turbulent mixing with physical surface tension and mass diffusion**	
15:25 ~ 15:55	**Coffee Break**
Session 8 (Chair: Alexandre Caboussat)	
15:55 ~ 16:40 **Monte Pettitt** University of Houston, U.S.A. **Title: Numerical Simulations of DNA Melting: Temperature vs mechanical strain**	
16:40 ~ 17:25 **Shaochun Chen** Zhengzhou University, China **Title: Nonconforming Anisotropic Finite Elements**	
17:25 ~ 17:45 **Lianwen Wang** University of Central Missouri, Warrensburg **Title: Approximate controllability of multiple delayed nonlinear control systems**	

July 11, 2008 (Friday)

9:00 ~ 15:00	**Tour Terra Cotta Army**
19:00	**Banquet(Celebration for Prof. Glowinski's 70th Birthday)**

July 12, 2008 (Saturday) **Room: Main building B--103**

Session 9 (Chair: Roland Glowinski)
8:30 ~ 9:15 **Bjorn Engquist** The University of Texas at Austin, U.S.A. **Title: Heterogeneous multiscale methods**
9:15 ~ 10:00 **Philippe G. Ciarlet** City University of Hong Kong, HongKong **Title: New unknowns in elasticity problems**
10:00 ~ 10:30 **Coffee Break**
Session 10 (Chair: Zhangxin Chen)
10:30 ~ 11:15 **William E. Fitzgibbon** University of Houston, U.S.A. **Title: Mathematical Models for the Spread of Infectious Disease Within Populations**
11:15 ~ 11:35 **Wenyuan Liao** The University of Calgary, Canada **Title: An implicit fourth-order finite difference scheme for solving Burgers' equation**
11:35 ~ 11:55 **Zhian Wang** University of Minnesota, U.S.A. **Title: Fast diffusion can prevent blow up in chemotaxis**
12：00-14：00 **Lunch**

July 12, 2008 (Saturday) **Room: Main building B--103**

Session 11 (Chair: Xiaobing Feng)
14:00-14:45 **Lihe Wang** University of Iowa, U.S.A. **Title: An inverse problem from geology**
14:45 ~ 15:05 **Lizhou Wang** Xi'an Jiaotong University, China **Title: On a nonlinear functional equation**
15:05 ~ 15:25 **Dongyang Shi** Zhengzhou University, China **Title: A New Lowest Order Nonconforming Mixed Finite ElementMethod For Second Order Elliptic Problems**
15:25 ~ 15:55 **Coffee Break**
Session 12 (Chair: Dongyang Shi)
15:55 ~ 15:15 **Jiang Zhu** National Laboratory for Scientific Computing, LNCC/MCT, Brazil **Title: A thermally coupled quasi-Newtonian flow**
15:15 ~ 16:35 **Xuejun Xu** Chinese Academy of Science, China **Title: Rigorous Spectral Analysis of Optimized Schwarz Methods with Robin Transmission Conditions**
16:35 ~ 16:55 **Wenjing Yan** Xi'an Jiaotong Universtiy, China **Title: The application of domain derivative of the Navier-Stokes equations in shape reconstruction**
16:55 ~ 17:15 **Yongjiang Yu** Shanghai Jiaotong University, China **Title: Global Existence of Solution and Asymptotic Analysis for MHD Equations On Thin Domains**

Titles and Abstracts

content

Numerical Solution of Non-Smooth Advection-Diffusion Problems Arising in Sand Mechanics

Alexandre Caboussat
Department of Mathematics, University of Houston, U.S.A.

Abstract

We present a simple model for the simulation of deposition processes in sand mechanics, including formation of sand piles on non-flat surfaces and sediment deposition in riverbeds. The sand height is modeled by a time-dependent advection-diffusion equation involving a fast/slow non-smooth diffusion operator. The diffusion operator contains a point-wise inequality constraint on the gradient of the solution that models the internal friction in the sand. It is reminiscent of the infinite Laplacian operator.

We present a splitting algorithm to decouple the advection operator from the non-smooth diffusion operator. The advection operator is treated with a stabilized (SUPG) finite element method. Piecewise linear finite elements are used for the discretization in space. We introduce an augmented Lagrangian method for the approximation of the fast/slow non-smooth diffusion operator. The inequality constraints on the solution and its gradient are treated by a proejction method and a penalization approach, together with a local Newton method.

Numerical results are presented for the simulation of the deposition of sand piles on flat and non-flat surfaces, and for the deposition of sediment on riverbeds. Extensions to water deposition on non-flat profiles is presented.

Nonconforming Anisotropic Finite Elements

Shaochun Chen
Zhengzhou University, Henan, China

Abstract

In this talk we present some nonconforming anisotropic finite elements which are convergent for any anisotropic meshes, i.e., the meshes can be any narrow and are not needed to satisfy the regular or non-degenerate condition.

The error of nonconforming finite elements includes interpolation error and consistence error. For the interpolation error we present a simple method to check the anisotropic interpolation condition. The analysis of consistence error of nonconforming elements is a problem, we present some methods to deal with it. We also presented some superconvergence results of the nonconforming elements on the anisotropic meshes.

The nonconforming anisotropic finite elements presented here include Wilson's element, Quasi-Wilson's element, Double Set Parameter rotated Q1 element for problems of order two; Morley's element, ACM element for problems of order four,etc.

Beyond CSS, SAGD, and VAPEX: Reservoir Modeling and Simulation for Heavy Oil and Oil Sands

Zhangxin Chen
University of Calgary and Southern Methodist University

Abstract

Heavy oil and oil sands are important hydrocarbon resources that are destined to play an increasingly critical role in the oil supply of the entire world. The oil sands in Alberta contain two (2) trillion barrels of oil. The important question is: How much of this oil is recoverable and what methods can be used? In this presentation, the speaker will present some of the recovery methods for heavy oil and oil sands: CSS (cyclic steam stimulation), SAGD (steam assisted gravity drainage), and VAPEX (vapor extraction). The differences between these methods and conventional recovery methods will be emphasized, and some open challenging problems in heavy oil and oil sands reservoir modeling and simulation will be discussed.

New unknowns in elasticity problems

Philippe G. Ciarlet
City University of Hong Kong, Hong Kong, China

Abstract

In the classical approach to elasticity problems, the components of the displacement field are the primary unknowns. In an "intrinsic" approach, new unknowns with a more "intrinsic", i.e. with more "mechanical" or "geometrical" meanings, such as a strain tensor field or a rotation field for instance, are instead taken as the primary unknowns. We survey here recent progress about the mathematical and numerical analysis of such methods.

Heterogeneous multiscale methods

Bjorn Engquist
Department of Mathematics, The University of Texas at Austin

Abstract

Continuum simulations of solids or fluids for which some atomistic information is needed are typical example of multi-scale problems with very large ranges of scales. For such problems it is necessary to restrict the simulations on the micro-scale to a smaller subset of the full computational domain. The heterogeneous multi-scale method is a framework for developing and analyzing numerical methods that couple computations from very different scales. Local micro-scale simulations on small domains supply missing data to a macro-scale simulation on the full domain. Examples are local molecular dynamics computations that produce data to a continuum macro-scale model, or a highly oscillatory dynamical system for which a local estimate of resonances is enough to supply data for a smoother evolution of averages.

Numerical Methods for Semigeostrophic Flows: A Fully Nonlinear Approach

Xiaobing Feng
Department of Mathematics, The University of Tennessee, U.S.A.

Abstract

Semigeostrophic flow equations, which model slowly varying flows constrained by rotation and stratification in meteorology and oceanography, are obtained by substituting the geostrophic balance relation into the Boussinesq form of the Euler equations for rotating stratified fluids. Based on a fully nonlinear reformulation of the semigeostrophic flow equations due to Benamou and Brenier (1998), we proposed a modified characteristic finite element method for computing the solution of the reformulated model. Our main idea is to use the vanishing moment method, which was recently developed by the author and collaborators, to handle the fully nonlinear Monge-Ampère type equation in the model. It is proved that the proposed modified characteristic finite element method enjoys optimal rate of convergence and error bounds. Numerical experiments will also be presented to illustrate the performance of the numerical methods.

This talk is prepared based on joint works with Michael Neilan of the University of Tennessee, U.S.A.

Mathematical Models for the Spread of Infectious Disease Within Populations

William E. Fitzgibbon
Department of Engineering Technology, College of Technology,
University of Houston, Houston, Texas, U.S.A.

Abstract

In an effort to describe the mathematical modeling of the spread of infectious disease through animal population we focus upon Feline Panleucoupenia Virus (FLVP). FLVP is a member of the parvoviridae family that infects all Felidae (cats) and other carnivore species as well. We begin with a discussion of the underlying population dynamics and then discuss four different mathematical models of varying degrees of complexity for the circulation of FLPV. Our discussion will include both the age structure and the spatial dispersion of the populations.

Adjoint Methods for Shape Optimization for the Viscous Incompressible Flow

Zhiming Gao
College of Science, Xi'an Jiaotong University, Xi'an, China

Abstract

This paper considers adjoint method for the optimal shape design of a body subjected to the minimum viscous dissipated energy in Navier–Stokes flows. The discretization of Navier–Stokes equations is accomplished by using standard Galerkin method and a new stabilized finite element method which utilizes a pair of spaces of finite element P1.P1 over triangles. The new method does not require selection of mesh-dependent stabilization parameters and has simple and straightforward implementations. We compute the Eulerian derivative of the cost functional by using theorems on the differentiability of a minimax and function space parameterization technique. We prove the effectiveness of the proposed gradient type algorithm with mesh adaptation and mesh movement strategies and compared the results for different Reynolds numbers with various finite element pairs.

Computation of the best constant in some Strauss-Nirenberg inequalities

Roland Glowinski
Department of Mathematics, University of Houston, U.S.A.

Abstract

Some inequalities due to Strauss and Nirenberg play a very important role in mathematical visco-plasticity. Since they have also practical implications the main goal of this presentation is to discuss the computation of the best constants involved in these inequalities. This leads to the solution of non-smooth eigenvalue problems. To solve these highly nonlinear problems we will combine finite element approximations with augmented Lagrangian based iterative methods. The numerical results not only justify the methodology which has been employed but they also suggest some conjectures of mathematical interest. This is joint work with Alexandre Caboussat.

Phase and Chemical Equilibrium Computation in Air Quality Modeling

Jiwen He
Department of Mathematics, University of Houston, Houston, Texas, U.S.A.

Abstract

The ability to model atmospheric processes involving trace gases and aerosols is crucial in predicting effects of changing anthropogenic emissions on urban and regional air pollution, global atmospheric chemistry, and global climate. Because of the wide variety of physical and chemical processes influencing aerosols, mathematical models of atmospheric aerosol dynamics are significantly more complex than those describing atmospheric trace gas behavior. In this talk, we focus on phase and chemical equilibrium problems related to mathematical modeling of physical states and chemical compositions of atmospheric aerosols. We analyze a class of thermodynamic modules for phase and chemical equilibrium computation that are based on primal-dual active-set/interior-point optimization methods. We conclude with numerical experiments showing that the proposed methods are efficient, computationally suitable for their incorporation into three dimensional air quality models.

Convergence Analysis of an Adaptive Interior Penalty Discontinuous Galerkin Method

Ronald H.W. Hoppe
Department of Mathematics, University of Houston, U.S.A.

Abstract

We are concerned with a convergence analysis of an adaptive symmetric Interior Penalty Discontinuous Galerkin (IPDG) method for second order elliptic boundary value problems. Based on a residual-type a posteriori error estimator, we prove that after each refinement step of the adaptive scheme we achieve a guaranteed reduction of the global discretization error in a mesh dependent energy norm associated with the IPDG method. In contrast to recent work on adaptive IPDG methods, the convergence analysis does not require multiple interior nodes for refined elements of the triangulation and thus leads to a more efficient adaptive scheme. In fact, it will be shown that bisection of elements is sufficient. The main ingredients of the proof of the error reduction property are the reliability and a perturbed discrete local efficiency of the estimator, a bulk criterion that takes care of a proper selection of edges and elements for refinement, and a perturbed Galerkin orthogonality property with respect to the energy inner product. A documentation of numerical experiments is given to illustrate the performance of the adaptive method.

The results are based on joint work with Guido Kanschat (Department of Mathematics, Texas A&M University, College Station) and Tim Warburton (Computational and Applied Mathematics (CAAM), Rice University, Houston).

On a Nonlinear Functional Equation

Lizhou Wang
School of Science, Xi'an Jiaotong University, Xi'an, China

Abstract

We prove that the nonlinear functional equation

$$u(x) = \frac{1}{2}(\sup_{D(x)} u + \inf_{D(x)} u) + r^2(x)f(x)$$

has a unique solution $u \in C(\bar{\Omega})$, where $D(x) = \bar{B}_{r(x)}(x), 0 < r(x) < d(x, \partial\Omega)$ and $f \geq 0$. We also present a comparison result for this equation.

Mechanism of the formation of singularities for quasilinear hyperbolic systems

Ta-Tsien Li
School of Mathematical Sciences, Fudan University, Shanghai, China

Abstract

In this survey talk the mechanism and the character of the formation of singularities caused by eigenvalues or(and) eigenvectors, respectively, will be discussed for 1-D quasilinear hyperbolic systems.

Boundary Shape Control of Navier-Stokes Equations and A Dimensional Splitting Method for 3D Navier-Stokes Equations

Kaitai Li
Xi'an Jiaotong University, Xi'an, China

Abstract

In this talk, a Geometrical Design Method for Blade's surface $\Im$ in the impeller is provided here $\Im$ is a solution to a coupling system consisting of the well-known Navier-Stokes equations and a four order elliptic boundary value problem . The coupling system is used to describe the relations between solutions of Navier-Stokes equations and the geometry of the domain occupied by fluids, and also provides new theory and methods for optimal geometric design of the boundary of domain mentioned above. This coupling system is the Eular-Lagrange equations of the optimal control problem which is describing a new principle of the geometric design for the blade's surface of an impeller. The control variable is the surface of the blade and the state equations are Navier-Stokes equations with mixed boundary conditions in the channel between two blades. The objective functional depending on the geometry shape of blade's surface describes the dissipation energy of the flow and the power of the impeller. First we prove the existence of a solution of the optimal control problem. Then we use a special coordinate system of the Navier-Stokes equations to derive the objective functional which depends on the surface Θ explicitly. We also show the weakly continuity of the solution of the Navier-Stokes equations with respect to the geometry shape of the blade's surface.

On the dimensional splitting method, 3D-flow domain is decomposed into a series of thin stream flow layers by a series of 2D-manifolds(surface) using calssical tensor anslysis method. Applied Euler backward difference scheme along normal direction to manifold, the compressible Navier-Stokes equations on the 2D-manifold are derived. According to this idea, a dimensional split method is proposed.this method is different from the classical domain decomposition method,in which one must result a 3D problem into each subdomain, but in our method we only solve a 2D-subproblem on 2D manifold,which is a quasi-Navier-Stokes equations on 2D manifold. In addition, the paper provide several numerical examples for turbomachinary flow.

An implicit fourth-order compact finite difference scheme for one-dimensional Burgers' equation

Wenyuan Liao
University of Calgary, Canada

Abstract

A fourth-order compact finite difference method is developed to solve one-dimensional Burgers' equation. The new method is based on the Hopf-Cole transformation, which transforms the original nonlinear Burgers' equation into a linear heat equation, which is solved by an implicit fourth-order compact finite difference scheme. Compact fourth-order formula is also developed to approximate the Robin boundary conditions, while the initial condition for the heat equation is approximated by Simpson's rule. Several numerical examples are given to demonstrate the efficiency and accuracy of this method.

Computational Methods for Molecule Orientations of Liquid Crystals and Liquid Crystal Flows

Ping Lin
Division of Mathematics, University of Dundee, Scotland, UK

Abstract

The liquid crystal molecule orientation is arranged by minimizing so-called Oseen-Frank energy functional. The energy is nonconvex due to the unit-length constraint of liquid crystal molecules and the constraint may be treated by the penalty method. The operator-splitting is efficient to deal with the penalty term. The liquid crystal flow is a coupling between a director field (molecule orientation) of liquid crystals and a flow field. The model is also related to phase field models in computing multiphase flows and a simple case of complex fluids. It is crucial to preserve the energy law of the system in numerical simulation, especially when orientation singularities are involved. We present a discrete energy law preserving C0 finite element method. It is of second order and matrix free in time. A number of liquid crystal flow examples (including small and large molecule cases) are computed to demonstrate the algorithm. We may also mention the application of the method to phase-field models of multi-phase flows and superconductivity models.

Turbulent mixing with physical surface tension and mass diffusion

Xinfeng Liu
University of California at Irvine, U.S.A.

Abstract

In this talk, I will introduce the local grid based front tracking method, which uses Lagrangian propagation and redistribution, but applies Eulerian reconstruction for the bifurcation of topology. A fully Lagrangian method is used to propagate the interface to obtain an accurate solution of

the interface position, and Eulerian reconstruction of the interface is only used in small regions where topological bifurcation is detected. This improved algorithm is shown extremely successful by simulation of turbulent mixing, such as the acceleration driven Rayleigh-Taylor instability, and among other complicated problems. I will also introduce a novel subgrid model to allow small but strictly positive amounts of numerical mass diffusion, and apply this model to Raleigh-Taylor mixing with excellent agreement to experiment. In addition, I will also compare related physical systems, with similar agreement to experiment.

Numerical Simulations of DNA Melting: Temperature vs mechanical strain

Monte Pettitt
Department of Chemistry, University of Houston, U.S.A.

Abstract

The polyelectrolyte nature of DNA greatly complicates the reaction coordinates for both association and melting. Here we consider mechanism of the melting of DNA. To study the melting transition of DNA, we performed a few molecular dynamics simulations of a homogeneous 12-basepair DNA d(A12)d(T12) with explicit water and ions at 400 K. The trajectories were analyzed with principal component analysis and revealed various processes which occurred on different time scales. A multistep mechanism is proposed where the untwisting of the duplex coupled with the breakup of the ion atmosphere is determined to be the rate-determining step of the melting process. To complement this study, DNA in twisted states of linking number from +10 to -10 were studied. The mechanical strain is intimately coupled to the ionic distributions which determines the relaxation mechanism.

Scientific computing for aluminum production

Jacques Rappaz
Institute of Analysis and Scientific Computing, EPFL, Switzerland

Abstract

The manufacturing process in the industry for aluminum production is to inject alumina Al_2O_3 in an electrolytic cell in order to obtain the chemical reaction: $2Al_2O_3 + electric\ energy \rightarrow 4Al + 3O_2$ The oxygen is burnt up by anodes: $C + O2 \rightarrow CO_2$ and the aluminum is collected at the cathodic bloc at the bottom of the cell. Two liquids are present in a cell. At the top, close to the anodes, there is the electrolytic bath in which the chemical reaction occurs. In the bath the dissolution of particles of alumina as well as the convection-diffusion of the dissolved alumina has to be considered. At the bottom of the cell, the liquid aluminum is deposed on the cathodic bloc. The temperature gradient in the cell leads to the formation of solid ledges on its walls.

A very strong electric current density $\overrightarrow{j}$ .ows through conductors into the hall which contains about a hundred electrolytic cells ($\sim 6000\ A/m^2$ in a cell). This current produces a strong magnetic induction field $\vec{B}$ ($\sim 1000\ Gauss$) which is absorbed in part by a steel shell supporting the device. It is important to consider the ferromagnetic screen eects when we want to know the magnetic induction field $\overrightarrow{B_i}$ inside the cell. This field, combined to the internal current density $\overrightarrow{j_i}$ give rise to Lorentz forces $\overrightarrow{j_i} \bigwedge \overrightarrow{B_i}$ which are responsible of hydro- dynamic eects leading to a velocity ..!u of the .uids which can reach 0.5m/s. The knowledge of the motion and the stability of the bath-aluminum interface is very important for obtaining a good working of the cell. Among the dierent approaches found in the literature in order to study this phenomenon, let us mention Fourier analysis of linear models (see for instance [1]), linear stability of MHD stationary solutions (see for instance [2],[3]), or numerical modeling of the dynamic MHD equations (see [4] and its references).

In this talk we present a numerical modeling in order to compute the current density $\overrightarrow{j_i}$, the magnetic induction field $\overrightarrow{B_i}$ with the screen effects of the steel shell, the motion of the fluids u and its interface. The dissolution of alumina and its distribution in the cell are considered as well as the thermal effects.

To do this, we numerically solve a system of coupled partial differential equations:

- An elliptic equation for the potential V to obtain the current $\overrightarrow{j_i} = \sigma\left(-\overrightarrow{\nabla}V + \overrightarrow{u} \bigwedge \overrightarrow{B_i}\right)$ which flows through the cell, where σ is the electric conductivity of the fluids,

- Maxwell equations to obtain $\overrightarrow{B}$ from the current density $\overrightarrow{j}$ and the equations modeling the magnetization effects of the steel shell,

- Incompressible Navier-Stokes equations with free surface to obtain the pressure p and the velocity $\overrightarrow{u}$ from the gravity forces $\rho\overrightarrow{g}$ and the electric forces $\overrightarrow{j_i} \bigwedge \overrightarrow{B_i}$,

- A kinetic transport equation to describe the dissolution of alumina particles and a convection-diffusion equation to obtain the distribution of liquid alumina,

- Heat equation with phase change (temperature and enthalpy) for the computation of the solid ledges which are formed on the wall of the cell.

All these equations are numerically solved with finite elements methods in space and splitting methods in time. The magnetic induction field and the magnetization of the steel shell are obtained from a domain decomposition method (see [6] and [5]). The free interface between liquid aluminum and the electrolytic bath is obtained from a level set technique coupled to a stabilized finite element method for solving Navier-Stokes equations (see [7]). The transport equation for the particles of alumina is solved by a characteristic method coupled to a streamline upwind technique for the convection-diffusion of dissolved alumina (see[8]). Finally the heat equation is solved with a Chernoff scheme which allows to obtain the enthalpy and the solid fraction of the bath (see [9]).

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[1] R. Moreau, D. Ziegler: Stability of aluminum cells, a new approach, Light Metals, 1986, 359-364.

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Transport equation for acoustic waves in Discrete Random Media

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Abstract

In this talk, we generalize well-established derivations of the radiative transport equation from first principles to model the energy density of time-dependent and monochromatic high frequency waves propagating in a random medium composed of localized scatterers. To do so, we assume that correlation length of the random scatterers is small compared to the overall distance of propagation so that ensemble averaging may take place. The correlation length may be either comparable to the typical wavelength in the system (the weak-coupling regime) or larger than the wavelength (the low-density regime). We will also mention briefly the application of the derived transport equation to imaging in random media. This is a joint work with Guillaume Bal at Columbia University.

A New Lowest Order Nonconforming Mixed Finite Element Method For Second Order Elliptic Problems

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Abstract

Consider the following second order elliptic problem

$$\begin{cases} -div(\beta\nabla u) = f, & x \in \Omega, \\ u = 0, & x \in \partial\Omega, \end{cases} \tag{1}$$

where $f \in L^2(\Omega)$ is a given function and $\beta \in L^\infty(\Omega)$ is assumed to be uniformly positive and bounded:

$$0 < a_1 \leq \beta \leq a_2,\ x \in \Omega.$$

Let $p = \beta\nabla u$, the problem (1) can be rewritten as

$$\begin{cases} p - \beta\nabla u = 0, & x \in \Omega, \\ divp = -f, & x \in \Omega, \\ u = 0, & x \in \partial\Omega. \end{cases} \tag{2}$$

Then the mixed variational formulation of (2) is to find $(p, u) \in H \times M$, such that

$$\begin{cases} a(p, v) + b(v, u) = 0, & \forall v \in H, \\ b(p, q) = -f(q), & \forall q \in M, \end{cases} \tag{3}$$

where

$$H = H(div; \Omega) = \{v \in (L^2(\Omega))^2,\ divv \in L^2(\Omega)\},\ M = L^2(\Omega),$$
$$a(p, v) = (\beta^{-1}p, v),\ b(v, q) = (divv, q), \forall v \in H,\ \forall q \in M,$$

and $(\cdot, \cdot)$ is the inner product of $L^2(\Omega)$ or $(L^2(\Omega))^2$.

The main aim of this talk is to present a new lowest order mixed nonconforming finite element scheme for (3). Based on some very distinct properties of the element discovered and novel approaches the optimal order error estimates are derived under the lowest requisition of the exact solution, which simplify the proof and improve the results of the previous literature. Numerical results are also given to verify our theoretical analysis.

This work is joint with Caixia Wang and supported by NSF of China (No.10671184).

Pattern Formation in a Rotating Suspension of non-Brownian particles

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Abstract

Non-equilibrium systems often organize themselves into interesting spatio-temporal structures or patterns. Examples include the patterns formed in bulk flow systems of pure fluids, in coating flows with a free surface, and in externally excited granular flows. In this talk, I will discuss a different class of flow systems of non-Brownian particles suspended in a Newtonian fluid. This system fills the gap between the two limiting cases of simple fluid flows and granular flows. Although single particle motion is known with high precision, the collective behavior of the particles often shows interesting but unexpected features. I will report our recent experimental studies of band and other pattern formation for settling and buoyant suspensions of uniform non-Brownian particles in a completely filled horizontal rotating cylinder [1-3]. These systems show a series of sharp pattern changes that are mapped out as a function of the rotation rate and fluid viscosity. The experiment suggests that the large number of patterns and rich dynamics found in the rotating cylinder result from the interplay among the viscous drag, gravitational and centrifugal forces.

⋆ This work was done in collaboration with W. R. Matson and B. J. Ackerson, and was supported in part by the Research Grants Council of Hong Kong SAR.

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The Dynamical Behavior and the Numerical Simulation of a Five-Modes Lorenz System of the MHD Equations For a Two-Dimensional Incompressible Fluid on a Torus

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Abstract

A model obtained by a five-mode truncation of the magnetic hydrodynamic (MHD) equations for a two-dimensional incompressible fluid on a torus $T^2 = [0, 2\pi] \times [0, 2\pi]$ is studied. First, we derive a model system by taking five modes in the Fouriers expansion, and then discuss the stability of stationary points of the five-modes system. Second, we find phenomena of Hopf bifurcation and chaos, and prove the existence of its attractor. Finally, we present a detailed numerical result of the whole process from bifurcation to chaos.

An inverse problem from geology

Lihe Wang
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Abstract

We will discuss a new numerical program about an inverse problem of geology. The first part of the problem is to find a reasonable boundary between different types of regions from the limited number of test sites. Then an effective numerical method is discussed for equation with sharp jumps.

Approximate controllability of multiple delayed nonlinear control systems

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Abstract

In this talk the approximate controllability for a class of control systems governed by semilinear multiple delayed integrodifferential equations. Some sufficient conditions for approximate controllability are established by using Schauder fixed point theorem. Several examples are given to illustrate the application of the obtained approximate controllability result.

Fast diffusion can prevent blow up in chemotaxis

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Abstract

Chemotaxis, the directed migration of cells in response to external chemical cues, is a fundamental cellular process and essential for development, tissue hemeostatis, wound healing, immune response and progression of many diseases such as angiogenesis Keller-Segel model is the well-known mathematical model describing chemotaxis. However this model demonstrates the blow up behavior of solutions which are irrelevant to reality in nature. In my talk, I will propose a mechanism, i.e., fast diffusion, to regularize the classical Keller-Segel model to allow global existence of solutions . The resulting model still demonstrates the aggregation patterns that chemotaxis model intrinsically has. Analytical results and numerical simulation will be shown. This is recent joint work with Y.S Choi from the University of Connecticut.

Rigorous Spectral Analysis of Optimized Schwarz Methods with Robin Transmission Conditions

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Abstract

In this talk, the tight relationship between Dirichlet-Neumann (D-N) operators and optimized Schwarz methods with Robin transmission conditions is discussed. We describe the spectral distribution of continuous D-N operators and give a rigorous spectral analysis of discrete D-N operators. By these results, we prove that optimized Schwarz methods with Robin transmission conditions cannot converge geometrically in the case of continuous problems. Furthermore, we get the accurate convergence rate of the two subdomains case. In addition, an estimation of convergence rate of optimized Schwarz methods with Robin transmission conditions is presented in the general case. Most of our results cannot be improved any more.

The application of domain derivative of the Navier-Stokes equations in shape reconstruction

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Abstract

This paper is concerned with the shape reconstruction of the newtonian viscous incompressible fluids driven by the stationary Navier–Stokes equations. By formulating the domain derivative of the nonhomogeneous Navier-Stokes equations and applying a regularized Gauss-Newton iterative algorithm , the numerical examples are given for recovering the shape. The results show that our theory is useful for practical purpose and the proposed algorithm is feasible.

Global Existence of Solution and Asymptotic Analysis for MHD Equations On Thin Domains

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Abstract

Magnetohydrodynamic(MHD) equations with Dirichlet or mixed Dirichlet-periodic boundary conditions on three-dimensional thin domains are considered. The global existence in time of the strong solutions of MHD equations for large initial data and force is obtained. Furthermore, the asymptotic analysis of MHD equations on thin domains is given when the thickness of the domains is small.

A thermally coupled quasi-Newtonian flow

Jiang Zhu
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Abstract

In this paper, we consider an incompressible quasi-Newtonian flow with a temperature dependent viscosity obeying a power law, and the thermal balance includes viscous heating. Some mathematical results such as existence and uniqueness are established, finite element approximation is proposed, and convergence analysis is presented.

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