CMSC2015

Workshop on Computational Mathematics & Scientific Computing to honor Max Gunzburger's 70th birthday Book of Abstracts

August19-22, 2015

Jeju Hana Hotel
Jeju Island, South Korea

AJOU UNIVERSITY

INHA UNIVERSITY

YONSEI BK21플러스
Department of Computational Science & Engineering

YONSEI UNIVERSITY
MATHEMATICS

Workshop on
Computational Mathematics & Scientific Computing
to honor **Max Gunzburger's 70th birthday**

Jeju Island, South Korea / August19-22, 2015

Day 1 - August 19 (Wednesday)

Time	Program
18:00-21:00	Registration and Social Hours

Day 2 - August 20 (Thursday)

Time	Program	Chair
09:00-10:00	**Max Gunzburger** FSU, USA	**Hyung-Chun Lee** Ajou U, Korea
10:00-10:30	**Break**	
10:30-11:00	**Qiang Du** Columbia U, USA	**Hongchul Kim** GWNU, Korea
11:00-11:30	**Ju Ming** BCSRC, China	
11:30-12:00	**Oleg Emanouilov** Colorado State U, USA	
12:00-14:00	**Lunch**	
14:00-14:30	**Hyesuk Kwon Lee** Clemson U, USA	**Youngmok Jeon** Ajou U, Korea
14:30-15:00	**Lili Ju** U of South Carolina, USA	
15:00-15:30	**Guannan Zhang** Oak Ridge National Lab, USA	
15:30-16:00	**Break**	
16:00-16:30	**Xiaoming He** MUST, USA	**Chang-Ock Lee** KAIST, Korea
16:30-17:00	**Clayton Webster** Oak Ridge National Lab, USA	
17:00-17:30	**Xioming Wang** FSU, USA	
18:00-20:00	**Conference Banquet**	

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Day 3 - August 21 (Friday)

Time	Program	Chair
08:40-09:00	**Hongchul Kim** GWNU, Korea	**Clayton Webster** Oak Ridge National Lab, USA
09:00-09:20	**Hyung-Chun Lee** Ajou U, Korea	
09:20-09:40	**Youngmok Jeon** Ajou U, Korea	
09:40-10:00	**Chang-Ock Lee** KAIST, Korea	
10:00-10:20	**Myungjoo Kang** SNU, Korea	
10:20-10:40	**Break**	
10:40-11:00	**Jeehyun Lee** Yonsei U, Korea	**Lili Ju** U of South Carolina, USA
11:00-11:20	**Hee-Dae Kwon** Inha U, Korea	
11:20-11:40	**Sungdae Yang** NIMR, Korea	
11:40-12:00	**Eunjung Lee** Yonsei U, Korea	
12:00-19:00	**Excursion**	

Day 4 - August 22 (Saturday)

Time	Program	Chair
09:00-12:00	Open discussion	**Max Gunzburger** FSU, USA

Webpage

http://cse.yonsei.ac.kr/cmsc2015.html

AJOU UNIVERSITY INHA UNIVERSITY YONSEI BK21 Department of Computational Science & Engineering YONSEI UNIVERSITY MATHEMATICS

POWER-LAW NOISES OVER GENERAL SPATIAL DOMAINS AND ON NONSTANDARD MESHES

HANS-WERNER VAN WYK, MAX GUNZBURGER*, JOHN BURKHARDT, AND MIROSLAV STOYANOV

Power-law noises abound in nature and have been observed extensively in both time series and spatially varying environmental parameters. Although recent years have seen the extension of traditional stochastic partial differential equations to include systems driven by fractional Brownian motion, spatially distributed scale-invariance has received comparatively little attention, especially for parameters defined over nonstandard spatial domains. This paper discusses the extension of power-law noises to general spatial domains by outlining their theoretical underpinnings as well as addressing their numerical simulation on arbitrary meshes. Three computational algorithms are presented for efficiently generating their sample paths, accompanied by numerous numerical illustrations.

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NONLOCAL BALANCE LAWS AND ASYMPTOTICAL COMPATIBLE SCHEMES

QIANG DU[1,2]

Nonlocality is ubiquitous in nature. We present some nonlocal balance laws that may be seen as generalizations to classical, local balance equations. As nonlocality vanishes, nonlocal equations recover local models. However, the nonlocal balance laws allow more general interactions and preserve more physical features than their local counterparts. We also discuss the convergence of numerical algorithms.

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STOCHASTIC HOMOGENIZATION OF AN OPTIMAL CONTROL PROBLEM

JU MING*

In this lecture we will investigate numerically and mathematically a class of optimal control problems where the state equations, given by second-order elliptic equations, have rapidly oscillating random coefficients. Without the assumption of periodicity or ergodicity, the existence of the optimal solutions in the framework of homogenization theory is discussed. Our conclusion implies that the stochastic optimization system will converge to a deterministic one in the sense of H-convergence.

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GLOBAL UNIQUENESS IN INVERSE BOUNDARY VALUE PROBLEMS FOR THE NAVIERSTOKES EQUATIONS AND LAM SYSTEM IN TWO DIMENSIONS

OLEG EMANOUILOV* AND MASAHIRO YAMAMOTO

We consider inverse boundary value problems for the NavierStokes equations and the isotropic Lam system in two dimensions. The question of global uniqueness for these inverse problems, without any smallness assumptions on unknown coefficients, has been a long-standing open problem for the NavierStokes equations and the isotropic Lam system in two dimensions. We prove the global uniqueness for both inverse boundary value problems. Our methodology is the same for both systems. The key is the construction of complex geometric optics solutions after decoupling the systems into weakly coupling systems.

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DECOUPLING ALGORITHMS FOR A FLUID-POROELASTIC SYSTEM

HYESUK LEE*

In this talk computational algorithms for the Stokes-Biot coupled system are discussed for the interaction of a free fluid with a poroelastic material. The decoupling strategy we employ is to cast the coupled fluid-poroelastic system as a constrained optimization problem with a Neumann type control that enforces continuity of the normal stress on the interface. The optimization objective is to minimize any violation of the other interface conditions. A numerical algorithm based on residual updating is presented for a least squares functional whose solution yields the minimizer of the constrained optimization problem.

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A FINITE ELEMENT THREE-DIMENSIONAL STOKES ICE SHEET DYNAMICS MODEL WITH ENHANCED LOCAL MASS CONSERVATION

LILI JU*

In this talk, we present and discuss a new finite element Stokes ice sheet dynamics model that enforces local element-wise mass conservation by enriching the pressure finite element space by adding the discontinuous piecewise constant pressure space to the Taylor-Hood pressure space. Through various numerical tests based on manufactured solutions, benchmark test problems, and the Greenland ice-sheet, we demonstrate that, for ice-sheet modeling, the enriched Taylor-Hood finite element model remains highly accurate and efficient, and is physically more reliable and robust compared to the classic Taylor-Hood finite element model.

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NUMERICAL SCHEMES FOR DECOUPLED FORWARD-BACKWARD STOCHASTIC DIFFERENTIAL EQUATIONS WITH JUMPS AND APPLICATION TO A CLASS OF NONLINEAR PARTIAL INTEGRO-DIFFERENTIAL EQUATIONS

GUANNAN ZHANG*, WEIDONG ZHAO, AND WEI ZHANG

We propose new numerical schemes for decoupled forward-backward stochastic differential equations (FBSDEs) with jumps, where the stochastic dynamics are driven by a d-dimensional Brownian motion and an independent compensated Poisson random measure. A semi-discrete scheme is developed for discrete time approximation, which is constituted by a classic scheme for the forward SDE and a novel scheme for the backward SDE. Under some reasonable regularity conditions, We prove that the semi-discrete scheme can achieve second-order convergence in approximating the FBSDEs of interest; and such convergence rate does not require jump-adapted temporal discretization. Next, to add in spatial discretization, a fully discrete scheme is developed by designing accurate quadrature rules for estimating the involved conditional mathematical expectations. Rigorous error analysis of the semi-discrete scheme is provided as several numerical examples that illustrate the effectiveness and efficiency of the proposed schemes.

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STOKES-DUAL-POROSITY MODEL AND FINITE ELEMENT METHOD FOR COUPLING DUAL-POROSITY FLOW AND FREE FLOW

XIAOMING HE*

We propose and numerically solve a new model considering transient flow in dual porosity media coupled with free flow in embedded conduits. Such situation arises, for example, for fluid flows in tight/shale reservoirs with macro-fractures or horizontal wellbores. The flow in dual-porosity media, which consists of both matrix and micro fractures, is described by a dual-porosity model. And the flow in the conduits is governed by the Stokes equation. The two models are coupled through four physically valid interface conditions on the interface between dual-porosity media and conduits, which play a key role in a physically faithful simulation with high accuracy. All the four interface conditions are constructed based on fundamental properties of the traditional dual-porosity model and Stokes-Darcy model. Due to the Stokes equation and the interface conditions which can provide more detail features of the flow around the conduits, the original dual-porosity model should be adjusted for the term of conduits/wells correspondingly. The weak formulation is derived for the proposed model and the existence and uniqueness of the solution are proved for the well-posedness of the model. A finite element method is proposed based on the weak formulation and the convergence is analyzed. Three numerical experiments are presented to validate the proposed model and illustrate the features of both the model and numerical method, such as the optimal convergence rate of the numerical solution, the detail flow information around conduits, and the applicability to the real world problems.

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A HYPERSPHERICAL ADAPTIVE SPARSE-GRID METHOD FOR HIGH-DIMENSIONAL DISCONTINUITY DETECTION

GUANNAN ZHANG, CLAYTON WEBSTER*, MAX GUNZBURGER, AND JOHN BURKHARDT

This work proposes and analyzes a hyperspherical adaptive hierarchical sparse-grid method for detecting jump discontinuities of functions in high-dimensional spaces. The method is motivated by the theoretical and computational inefficiencies of well-known adaptive sparse-grid methods for discontinuity detection. Our novel approach constructs a function representation of the discontinuity hypersurface of an N-dimensional discontinuous quantity of interest, by virtue of a hyperspherical transformation. Then, a sparse-grid approximation of the transformed function is built in the hyperspherical coordinate system, whose value at each point is estimated by solving a one-dimensional discontinuity detection problem. Due to the smoothness of the hypersurface, the new technique can identify jump discontinuities with significantly reduced computational cost, compared to existing methods. Moreover, hierarchical acceleration techniques are also incorporated to further reduce the overall complexity. Rigorous complexity analyses of the new method are provided as are several numerical examples that illustrate the effectiveness of the approach.

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AN UNCONDITIONALLY STABLE AND EFFICIENT 2ND ORDER ACCURATE SCHEME FOR THE CAHN-HILLIARD-DARCY SYSTEM

XIAOMING WANG*

We present a novel 2nd order in time unconditionally stable and efficient algorithm for the Cahn-Hilliard-Darcy system that models two-phase flow in porous media or two-phase flow in Hele-Shaw cell. The scheme is efficient since it decouples the phase-field variable from the velocity variable. Moreover, the method also decouples the velocity and the pressure field. Our numerical experiments supports our theoretical result. This is a joint work with Daozhi Han.

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A BOUNDARY CONTROL PROBLEM FOR VORTICITY MINIMIZATION IN TIME-DEPENDENT 2D NAVIER-STOKES EQUATIONS

HONGCHUL KIM*

We deal with a boundary control problem for the vorticity minimization, in which the flow is governed by the timedependent two dimensional incompressible Navier-Stokes equations. We derive a mathematical formulation and a process for an appropriate control along the portion of the boundary to minimize the vorticity motion due to the flow in the fluid domain. After showing the existence of an optimal solution, we derive the optimality system for which optimal solutions may be determined. The dfferentiability of the state solution in regard to the control parameter shall be conjunct with the necessary conditions for the optimal solutions.

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GALERKIN METHOD FOR STOCHASTIC CONTROL PROBLEMS

HYUNG-CHUN LEE* AND JANGWOON LEE

In an interdisciplinary field on mathematics and physics, we examine a physical problem, fluid flow in porous media, which is represented by a stochastic partial differential equation (SPDE). We first give a priori error estimates for the solutions to an optimization problem constrained by the physical model under lower regularity assumptions than the literature. We then use the concept of Galerkin finite element methods to establish a new numerical algorithm to give approximations for our stochastic optimal physical problem. Finally, we develop original computer programs based on the algorithm and use several numerical examples of various situations to see how well our solver works by comparing its outputs to the priori error estimates.

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THE HYBRID DIFFERENCE METHODS FOR THE ELLIPTIC AND NAVIER-STOKES EQUATIONS

YOUNGMOK JEON*

In this presentation we introduce the hybrid differences(HDM) for the elliptic and Navier-Stokes equations. The HDM is a finite difference version of the hybridized discontinuous Galerkin method. The HDM is comparable with the finite difference method (FDM). The main difference between the FDM and HDM is that the FD formula of a single type is deployed for all interior nodes in the FDM, while the cell finite difference and the interface difference are combined in the HDM. The finite difference method is simple to implement and it can solve many physical problems efficiently. The HDM is as easy to implement as the FDM, and it apparently seems to possess several advantages over the FDM. Those advantages are listed below.

(1) The method can be applied to nonuniform grids, retaining the optimal order of convergence. The FD formulas in a reference cell can be applied to cells of any dimension, multiplied by scaling factors.
(2) Numerical methods with an arbitrarily high order convergence can be obtained in an easier way by locating more cell points.
(3) Problems on a complicated geometry can be treated reasonably well, and the boundary condition can be imposed exactly on the exact boundary (no variational crime).
(4) Stability problems when solving the Stokes/Navier-Stokes problem can be resolved without introducing a staggered grid or a stream-vorticity formulation. Therefore, the HDM requires less programming efforts compared to the staggered grid method, and the method can be applied without dimensionality restriction.
(5) In the HDM the grids for pressure are sub-located on the grids for velocity fields for flow problems.
(6) Numerical analysis is based on a discrete divergence theory on each cell.
(7) The flux conservation property holds in each cell and flux continuation holds across intercell boundaries.
(8) The embedded static condensation property of the HDM reduces degrees of freedom a lot.

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A UNIFIED APPROACH FOR OVERLAPPING AND NONOVERLAPPING DOMAIN DECOMPOSITION METHODS FOR THE TOTAL VARIATION MINIMIZATION

CHANG-OCK LEE*

In this talk, we provide a unified apprach for overlapping and nonoverlapping domain decomposition methods for the total variation minimization. We decompose the domain into rectangular subdomains, where the local total variation problems are solved with first-order primaldual algorithm. The convergence of the algorithms is analyzed under certain assumptions and numerical results are to be shown.

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SIMULTANEOUS CARTOON AND TEXTURE IMAGE RESTORATION WITH HIGHER-ORDER REGULARIZATION

MIYOUN JUNG AND MYUNGJOO KANG*

This article introduces a variational color image decomposition and restoration model. The aim is to recover an image from its degraded version, while simultaneously decomposing the image into its cartoon and texture components. The energy involves adaptive higher-order regularizers, incorporated with an edge indicator function. This not only helps cartoon and texture decomposition, but also provides higher quality image restoration by ameliorating the staircasing effect that arises in total variation regularization methods. To realize the proposed models, we present fast and efficient iterative algorithms based on a variable splitting scheme and an augmented Lagrangian method. A convergence analysis of the proposed algorithms is also presented under certain conditions. Numerical results and comparisons demonstrate that the proposed model is more effective than state-of-the-art methods for both image decomposition and restoration.

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REAL TIME ESTIMATION OF THE REPRODUCTION NUMBER USING KALMAN FILTER

JEEHYUN LEE*

Estimation of reproduction number in epidemiology is one of the most important issues because it helps determine whether or not an infectious disease can spread through a population. The basic reproduction number is the expected number of secondary infection cases produced by an index case in a completely susceptible population. Real time estimation, by contrast, shows how the reproduction number changes in accordance with counter measures. It is very challenging to estimate these parameters due to the properties of epidemiology including non-reproducible and incomplete epidemic data. In this research, to overcome difficulties in least square method (LSM), a standard approach for parameter estimations, we apply ideas and techniques of Kalman filter (KF). Numerical simulations show that KF has a great potential as a tool for real time parameter estimations and is applied to the national data of antiviral agent prescription in Korea for Pandemic Influenza A(H1N1) 2009 to estimate the running reproduction number.

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FEEDBACK CONTROL OF AN HBV MODEL BASED ON DIFFERENTIAL EVOLUTION AND KALMAN FILTER

HEE-DAE KWON*

In this talk, we investigate viral dynamics of hepatitis B using a mathematical model which is in the form of a system of ordinary differential equations. We show that the proposed model has one virus-free steady state and a chronic steady state. We conduct a local stability analysis of these steady states based on the basic reproduction number. A model predictive control (MPC) based on the differential evolution (DE) method is proposed to design (sub)optimal treatment regimes. In addition, the problem of implementing the DE methodology and the extended Kalman filter (EKF) with inaccurate or incomplete observation data and long measurement periods is addressed. Numerical results indicate the effects of two types of dynamic treatments representing reverse transcriptase (RT) inhibitors and protease inhibitors (PIs) in minimizing both the virus population and infected cells.

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THE EVALUATION OF RAIN/NO-RAIN CLASSIFICATION METHOD USING KALMAN FILTER FOR BRIGHTNESS TEMPERATURE OVER THE KOREAN PENINSULA

SUNG-DAE YANG*, GEUN-HYEOK RYU, KI-HONG PARK, AND JIN-HO SHIN

In this study, the sensitivity test was carried out with the satellite brightness temperature (TBs) with respect to COMs cloud data and radar rainfall estimates. Then the comparison of standard resolution (14km14km) and high resolution (7km7km) of TBs (21V, 85V) was performed by computing each probability density function of various seasons under no-rain conditions. Finally we proposes Kalman filter methods which are applied to the TBs in order to reduce the effects (or noises) of geographical and geophysical variability of satellite brightness temperature data according to the results of the first two tests. The newly proposed method is applied to the rain/no-rain classification (RNC), and is compared with the previous RNC methods by ROC (Receiver Operating Characteristic) analysis. In the results, spring and fall seasons show relatively low accuracy for rain/no-rain classification, and so it is needed to adjust the coefficients of scattering index (SI) over land around the Korean peninsula. The brightness temperature data with the Kalman filter method provides the increased accuracy for the classification.

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DEPTH FORMULA USING EIT IN ANOMALY DETECTION WHICH IS INDEPENDENT ON ADMITTIVITY CONTRAST

EUNJUNG LEE*

The trans-admittance mammography (TAM) was introduced to improve spatial resolution of impedance imaging in detecting the malignant breast tumor tissue. The TAM model places the breast in between two electrical plates which is similar to X-ray mammography configuration. The top plate is a large single voltage applying electrode and the bottom plate, whose potential is kept at ground, is consisted of many small gold plated sensing electrodes arrayed in rectangular shape. When voltages with various frequencies are applied, we collect the Neumann data measured from the sensing electrodes. In this talk, we discuss about the mathematical analysis which has not been done from the previous papers from observing an interaction between the size of cancerous cell and the frequency difference of electrical current owing outward from bottom sensing electrodes by taking advantage of layer potential tools. Furthermore, numerical simulation successfully shows the feasibility of the proposed tumor estimating analysis.

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