Workshop on Recent Advances in Scientific and Engineering Computation

May 4-7, 2017

Institute of Natural Sciences, Shanghai Jiao Tong University

Contents

1 General Information

Introduction

The field of scientific and engineering computation is experiencing fast and significant advances over the past years. This workshop is aimed to bring together researchers in the field to present recent advances and explore possible collaborations.

Date

May 4-7, 2017

Organizers

- Shi Jin, Shanghai Jiao Tong University
- Min Tang, Shanghai Jiao Tong University
- Wenjun Ying, Shanghai Jiao Tong University

2 Schedule

2017-05-04

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09:15 - 10:00	Tiegang Liu	Beihang University	Adaptive Mesh Refinement Based on Continuous Adjoint Method
10:30 - 11:15	Ziqing Xie	Hunan Normal University	Normalized Goldstein-type Local Minimax Method (NG-LMM) for Finding Multiple Solutions of Semilinear PDEs
11:15 - 12:00	Liwei Xu	University Of Electronic Science And Technology Of China	Numerical methods for solving problems in unbounded domains
14:00 - 14:45	Hongxing Rui	Shandong University	Stability and Superconvergence of MAC Scheme for Stokes Equations on Non-uniform Grids

14:45 - 15:30	Chunxiong Zheng	Tsinghua University	Fast Algorithm for the Exterior Problem of Elliptic Equations in Three Dimensions
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2017-05-05

Time	Speaker	Affiliation	Title
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09:15 - 10:00	Zhongyi Huang	Tsinghua University	Bloch Decomposition-based Stochastic Galerkin/Collocation Method for Schrodinger Equation with Random Inputs
10:20 - 11:05	Hui Zhang	Beijing Normal University	Invariant Energy Quadratization Approach for Incompressible Smectic-A Liquid Crystal Flow
11:05 - 11:50	Tao Zhou	Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences	Parareal Algorithms: Theory and Applications
14:00 - 14:45	Xiaoping Xie	Sichuan University	Robust a Posteriori Error Estimation for a Weak Galerkin Finite Element Discretization of Stokes Equations
14:45 - 15:30	Hao Wu	Tsinghua University	The Quadratic Wasserstein Metric for Earthquake Location
15:50 - 16:35	Xianmin Xu	Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences	Trace Finite Element Methods for Partial Differential Equations on Evolving Surfaces
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2017-05-06

Time	Speaker	Affiliation	Title
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09:15 - 10:00	Haijun Yu	Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences	Analysis of Minimum Action Method for Non-gradient Systems
10:20 - 11:05	Weiguo Gao	Fudan University	Jacobi-like Algorithm for Bethe-Salpeter Eigenvalue Problem
11:05 - 11:50	Yana Di	Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences	Numerical Simulation of Vlasov Equation Using Moment Expansion Method
14:00 - 14:45	Juan Cheng	Institute of Applied Physics and Computational Mathematics	High Order Positivity-preserving and Symmetry-preserving Conservative Lagrangian Schemes for Compressible Euler Equations
14:45 - 15:30	Zhiqiang Sheng	Institute of Applied Physics and Computational Mathematics	A Nonlinear Finite Volume Scheme for Diffusion Equation on Distorted Meshes
15:50 - 16:35	Ran Zhang	Jilin University	The Weak Galerkin Finite element Method for Eigenvalue Problems
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17:20 - 17:50	Zheng Ma	Shanghai Jiao Tong University	Uncertainty Quantification for Linear Transport Equation with Random Inputs

2017-05-07

Time	Speaker	Affiliation	Title
08:30 - 09:15	Yanren Hou	Xi’an Jiaotong University	Well-Posedness of Coupled Stokes/Darcy Model with Beavers-Joseph Interface Condition for any Physical Parameters

09:15 - 10:00	Guoxian Chen	Wuhan University	A New Hydrostatic Reconstruction Scheme Based on Subcell Reconstructions
10:20 - 11:05	Huoyuan Duan	Wuhan University	With or Without de Rham Complex Exact Sequence in FEM in the Computation of Maxwell Equations
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3 Abstract

3.1 2017-05-04

3.1.1 Opening Remark (Weike Wang)

Weike Wang, Shanghai Jiao Tong University
2017-05-04 08:20 - 08:30

3.1.2 High-Order Accurate Physical-Constraints-Preserving Schemes for Special Relativistic Hydrodynamics (Huazhong Tang)

Huazhong Tang, Peking University
2017-05-04 08:30 - 09:15

Relativistic hydrodynamics (RHD) plays an essential role in many fields of modern physics, e.g. astrophysics. Relativistic flows appear in numerous astrophysical phenomena from stellar to galactic scales, e.g. active galactic nuclei, super-luminal jets, core collapse super-novae, X-ray binaries, pulsars, coalescing neutron stars and black holes, micro-quasars, and gamma ray bursts, etc. The relativistic description of fluid dynamics should be taken into account if the local velocity of the flow is close to the light speed in vacuum or the local internal energy density is comparable (or larger) than the local rest mass density of the fluid. It should also be used whenever matter is influenced by large gravitational potentials, where the Einstein field theory of gravity has to be considered. The dynamics of the relativistic systems requires solving highly nonlinear equations and the analytic treatment of practical problems is extremely difficult. Hence, studying them numerically is the primary approach.

We develop high-order accurate physical-constraints-preserving finite difference WENO schemes for special relativistic hydrodynamical (RHD) equations, built on the local Lax-Friedrich splitting, the WENO reconstruction, the physical-constraints-preserving flux limiter, and the high order strong stability preserving time discretization. They are formal extensions of the existing positivity-preserving finite difference WENO schemes for the non-relativistic Euler equations. However, developing physical-constraints-preserving methods for the RHD system becomes much more difficult than the non-relativistic case because of the strongly coupling between the RHD equations, no explicit expressions of the conservative vector for the primitive variables and the flux vectors, and one more physical constraint for the fluid velocity in addition to the positivity of the rest-mass density and the pressure. The key is to prove the convexity and other properties of the admissible state set and discover a concave function with respect to the conservative vector replacing the pressure which is an important ingredient to enforce the positivity-preserving property for the non-relativistic case.

Several numerical examples are used to demonstrate accuracy, robustness, and effectiveness of the proposed physical-constraints-preserving schemes in solving relativistic problems with large Lorentz factor.

3.1.3 Adaptive Mesh Refinement Based on Continuous Adjoint Method (Tiegang Liu)

Tiegang Liu, Beihang University
2017-05-04 09:15 - 10:00

An adaptive mesh refinement algorithm based on continuous adjoint approach is developed. Both of the primal and adjoint equations are approximated by discontinuous Galerkin method. The proposed adaptive algorithm is applied to 2D compressible flows. Some numerical tests are made to demonstrate the superiority of the adaptive algorithm.

This is joint work with Huiqiang Yue.

3.1.4 Normalized Goldstein-type Local Minimax Method (NG-LMM) for Finding Multiple Solutions of Semilinear PDEs (Ziqing Xie)

Ziqing Xie, Hunan Normal University
2017-05-04 10:30 - 11:15

In this talk, we proposes a normalized Goldstein-type local minimax method (NG-LMM) to find multiple minimax-type solutions. Although borrowing the idea of the classical Goldstein line search in the optimization theory in R^n, which is aimed to guarantee a large-scope convergence of some descent algorithms, the NG-LMM has to be modified to be suitable for solving multiple solutions of semilinear elliptic PDEs both in numerical implementation and theoretical analysis. Compared with the normalized Armijo-type local minimax method (NA-LMM) and its updated version introuduced by Zhou and Li(SISC, 2001, 2002) and Xie, Yuan and Zhou(SISC, 2012), in which the step-size has to be controlled artificially, our approach can prevent step-size from being too small automatically and then ensure that the iterations make reasonable progress. The feasibility of the NG-LMM is provided and its corresponding global convergence is proven rigoriously. Finally, it is implemented to solve several typical semi-linear elliptic boundary value problems on a square or dumbbell for multiple saddle points and the numerical results indicate that this approach is very efficient. Under the weaker assumption that the peak selection is only continuous, we "almost" say "yes" to the question: Are the line search rules in the optimization theory suitable for finding multiple unstable solutions of semilinear PDEs with variational structure by some modification?

Keywords: Semilinear elliptic PDEs, global convergence, multiple solutions, local minimax method, normalized Goldstein-type search rule

3.1.5 Numerical methods for solving problems in unbounded domains (Liwei Xu)

Liwei Xu, University Of Electronic Science And Technology Of China
2017-05-04 11:15 - 12:00

It is known that some other methods are usually required to be coupled with such field equation solver as finite element methods for the solution of problems in unbounded domains. In this talk, we first give a literature review on the coupling methods of finite element methods with Fourier series based Dirichlet-to-Neumann (DtN) methods and boundary integral equation methods, and then present our recent work on these two techniques. Finally, we discuss a direct method, boundary integral equation method, solving the scattering problem in unbounded domain. Essential analysis and numerical results will be presented to demonstrate the accuracy of the methods.

References:

[1] Tao Yin, Liwei Xu, Analysis of Dirichlet-to-Neumann boundary conditions for Helmholtz equations: fluid-solid interaction problems.

[2] George C. Hsiao, Liwei Xu, Shangyou Zhang, Nonsingular kernel boundary integral and finite element coupling method, submitted.

[3] Gang Bao, Liwei Xu, Tao Yin, An accurate boundary element method for the exterior elastic scattering problem, submitted.

[4] Tao Yin, George C. Hsiao, Liwei Xu, Boundary integral equation methods for the two dimensional fluid-solid interaction problem, SIAM Num. Ana. Minor revision.

3.1.6 Stability and Superconvergence of MAC Scheme for Stokes Equations on Non-uniform Grids (Hongxing Rui)

Hongxing Rui, Shandong University
2017-05-04 14:00 - 14:45

The marker and cell (MAC) method, a finite volume method based on staggered grids, has been one of the simplest and most effective numerical schemes for solving the Stokes and Navier-Stokes equations. Its superconvergence on uniform grids has been observed since 1992 but numerical analysis was not obtained completely. In this paper we establish the LBB condition and the stability for both velocity and pressure for MAC scheme of Stokes equations on non-uniform grids. Then we construct a auxiliary function depending on the velocity and discretizing parameters and analyze the superconvengence by using this function. We obtain the second order superconvergence in L2 norm for both velocity and pressure for the MAC scheme. We also obtain the second order superconvergence for some terms of H1 norm of the velocity, and the other terms of H1 norm are second order superconvergence on uniform grids. Numerical experiments using the MAC scheme show agreement of the numerical results with theoretical analysis.

3.1.7 Fast Algorithm for the Exterior Problem of Elliptic Equations in Three Dimensions (Chunxiong Zheng)

Chunxiong Zheng, Tsinghua University
2017-05-04 14:45 - 15:30

Artificial boundary method is a popular method for handling PDE problems in unbounded domains. For three-dimensional problem, the evaluation of boundary DtN mapping presents a great numerical difficulty. Take the exterior Poisson problem as an example, the exact DtN mapping involves a square root of an elliptic operator on the spherical artificial boundary. In this talk, we report our fast algorithm based on the Pade approximation.

3.1.8 A multiscale kinetic scheme for collisional Vlasov Poisson equations (Guoxi Ni)

Guoxi Ni, Institute of Applied Physics and Computational Mathematics, Beijing
2017-05-04 15:50 - 16:35

We propose a multiscale kinetic scheme for a collisional Vlasov Poisson (VP) system. In order to capture non-equilibrium state of the distribution function,the unified gas kinetic scheme (UGKS) has been used for the construction of the numerical solution for the system. Due to the periodic boundary condition, the Poisson equation for electric field is solved by the fast Fourier transform (FFT) method.By combining the UGKS and FFT, an efficient scheme for the collisional VP system has been obtained. The present scheme is able to accurately capture the numerical solutions in both kinetic and diffusive regimes. This scheme is asymptotic preserving with the variation of the ratio between the mean free path and the numerical cell size.Numerical tests validate the efficiency and accuracy of the scheme.

3.1.9 A Hybridizable Discontinuous Galerkin Method for Elliptic Interface Problem in the Formulation of Boundary Integral Equations (Haixia Dong)

Haixia Dong, Beijing Computational Science and Research Center
2017-05-04 16:35 - 17:05

In this work we present a new numerical method for the general elliptic interface problem whose diffusion coefficients are piecewise constant. This method reformulates the elliptic interface problem as a Fredholm boundary integral equation of the second kind, and further solves the integral equation iteratively with GMRES method. In each iteration, evaluation of boundary and volume integrals is done by solving equivalent but simple interface problems, which be solved by hybridizable discontinuous Galerkin method under unfitted mesh. One key advantage of using hybridizable discontinuous Galerkin method is that the interpolation for evaluating boundary integrals on interface is only done element by element using linear Lagrange polynomial. Numerical experiments show that the method yields second-order accurate results even for cases with high contrast diffusion coefficients.

This is joint work with Wenjun Ying and Jiwei Zhang.

3.2 2017-05-05

3.2.1 A Modified WENO Schemes for Hyperbolic Conservation Laws (Jianxian Qiu)

Jianxian Qiu, Xiamen University
2017-05-05 08:30 - 09:15

In this presentation, a class of modified weighted essentially non-oscillatory (MWENO) schemes is presented in the finite difference framework for solving the hyperbolic conservation laws. These schemes adapt between the linear upwind scheme and the WENO scheme automatically by the usage of a new simple switching principle. The methodology to reconstruct numerical fluxes for the MWENO schemes is split into two parts: if all extreme points of the reconstruction polynomial for numerical flux in the big spatial stencil are located outside of the stencil, the the numerical flux is approximated directly by the reconstruction polynomial, and the approximation is a linear and high order accuracy; otherwise the WENO procedure in G.-S. Jiang and C.-W. Shu, J. Comput. Phys., 126 (1996), 202-228 is applied to reconstruct the numerical flux. The main advantage of these new MWENO schemes is their robustness and efficiency comparing with the classical WENO schemes specified in G.-S. Jiang and C.-W. Shu, J. Comput. Phys., 126 (1996), 202-228. The MWENO schemes can be applied to compute some extreme test cases such as the Sedov blast wave, the Leblanc and the high Mach number astrophysical jet problems et al. by using a normal CFL number without any further positivity preserving procedure for the purpose of controlling the concurrence of the negative density and pressure.

Extensive numerical results are provided to illustrate the good performance of the MWENO schemes.

This is joint work with Jun Zhu, Nanjing University of Aeronautics and Astronautics.

3.2.2 Bloch Decomposition-based Stochastic Galerkin/Collocation Method for Schrodinger Equation with Random Inputs (Zhongyi Huang)

Zhongyi Huang, Tsinghua University
2017-05-05 09:15 - 10:00

In this talk, we focus on the analysis and numerical methods for the Schrodinger equation with lattice potential and random inputs. This is an important model in solid state physics where randomness is involved to describe some complicated phenomena that are not exactly known. Here we recall the well-known Bloch decomposition-based split-step pseudospectral method where we diagonalize the periodic part of the Hamilton operator so that the effects from dispersion and periodic lattice potential are computed together. Meanwhile, for the random nonperiodic external potential, we utilize the generalize polynomial chaos with Galerkin procedure to form an ode system which can be solved analytically. Furthermore, we analyze the convergence theory of the stochastic collocation method for the linear Schrodinger equation with random inputs. Based on the interpolation theories, the convergence rate depends on the regularity of the solution with respect to the random variables. Hence, we investigate the dependence of the regularity of the solution on that of the random potential and initial data. We provide sufficient conditions on the random potential and initial data to ensure the spectral convergence.

This is joint work with Zhizhang Wu.

3.2.3 Invariant Energy Quadratization Approach for Incompressible Smectic-A Liquid Crystal Flow (Hui Zhang)

Hui Zhang, Beijing Normal University
2017-05-05 10:20 - 11:05

In this talk, we construct the first-order decoupled and the second-order coupled temporal accurate energy stable schemes to solve the smectic-A liquid crystals model in the incompressible fluid. This model involves the incompressible Navier-Stokes equation and a fourth order phase-field equation for the order parameter of smectic-A liquid crystals. The projection method is adopted to decouple the pressure and the velocity in the Navier-Stokes equation. Moreover, the Invariant Energy Quadratization method is used to linear the nonlinear functionals, meanwhile preserving the energy stability. Then we present the fully discrete energy stable schemes by using finite differences in time and $C^0 - finite$ elements in space where the fourth order equation shall be transformed into two second order equations. At last we calculate several numerical tests to illustrate the temporal accuracy of the proposed schemes and verify that our schemes are unconditionally energy stable. Moreover, we simulate the process of undulation in the smectic-A liquid crystals under the effect of the shear flows and the magnetic field, which is consistent with other works.

3.2.4 Parareal Algorithms: Theory and Applications (Tao Zhou)

Tao Zhou, *Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences*
2017-05-05 11:05 - 11:50

The talk starts with a brief introduction to the parareal (parallel in time) algorithms. We shall review the basic ideas and some fundemental analysis results. Then, their applications to uncertainty quantification (UQ) and fractional PDEs will also be discussed.

3.2.5 Robust a Posteriori Error Estimation for a Weak Galerkin Finite Element Discretization of Stokes Equations (Xiaoping Xie)

Xiaoping Xie, *Sichuan University*
2017-05-05 14:00 - 14:45

We propose a robust residual-based a posteriori error estimator for a weak Galerkin finite element method for Stokes equations in two and three dimensions. The estimator consists of two terms. The first term characterizes the difference between the L^2-projection of the velocity approximation on the element interfaces and the corresponding numerical trace, and the second term is related to the jump of the velocity approximation between the adjacent elements. We show that the estimator is reliable and efficient through two estimates of global upper and global lower bounds, up to two data oscillation terms caused by the source term and the nonhomogeneous Dirichlet boundary condition. The estimator is also robust in the sense that the constant factors in the upper and lower bounds are independent of the viscosity coefficient. Numerical results are provided to verify the theoretical results.

This is joint work with Xiaobo Zheng.

3.2.6 The Quadratic Wasserstein Metric for Earthquake Location (Hao Wu)

Hao Wu, *Tsinghua University*
2017-05-05 14:45 - 15:30

In [Engquist et al., Commun. Math. Sci., 14(2016)], the Wasserstein metric was successfully applied to the full waveform inversion. We apply this method to the earthquake location problem. The convexity of the misfit function with respect to the earthquake hypocenter is discussed theoretically for the situation of constant velocity model and is illustrated experimentally in all the examples. The computational efficiency is significantly increased by introducing the Levenberg-Marquardt method to the optimization problem.

3.2.7 Trace Finite Element Methods for Partial Differential Equations on Evolving Surfaces (Xianmin Xu)

Xianmin Xu, Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences
2017-05-05 15:50 - 16:35

Many industrial processes and biological phenomena could be modeled by partial differential equations on surfaces or manifolds. Recently, these problems have attracted much interest in the community of numerical analysis. In this talk, I will introduce some trace finite element methods for convection-diffusion equations on evolving surfaces. The methods are based on an Eulerian framework and easily treat shape and topology changes of the surface.

3.2.8 Uniformly Convergent Scheme for Strongly Anisotropic Diffusion Equations with Closed Field Lines (Yihong Wang)

Yihong Wang, Shanghai Jiao Tong University
2017-05-05 16:35 - 17:05

Diffusion in magnetized plasma is highly anisotropic. The anisotropy ratio may reach up to the order of 10^{12}. Discretization of magnetic fields with closed field lines by field-aligned grids lead to ill-posed system while discretization by non-field-aligned grids may degenerates the convergence rate and accuracy order. This talk will introduce a simple but efficient asymptotic preserving scheme for the problem. The new method removes the ill-posedness of the original problem by introducing a global condition along each closed field line, which is just slightly modified and different from the standard scheme, while it preserves the formal (second-order) order of accuracy of the discretization even in the asymptotic limit. Numerical examples in two space dimensions will be presented to demonstrate the algorithm.

This is joint work with Wenjun Ying and Min Tang.

3.3 2017-05-06

3.3.1 非平衡辐射能量方程组的性质与离散格式 (Guangwei Yuan)

Guangwei Yuan, Institute of Applied Physics and Computational Mathematics
2017-05-06 08:30 - 09:15

在天体物理、大气物理和惯性约束聚变物理等应用领域中，需要对辐射在物质中的传输、并与物质发生相互作用的物理过程进行精密化数值模拟。通常采用非平衡辐射建模来描述这类辐射传输问题。本报告将简要介绍非平衡辐射能量方程组的基本数学性质，以及保持这些性质的离散格式。

3.3.2 Analysis of Minimum Action Method for Non-gradient Systems (Haijun Yu)

Haijun Yu, Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences
2017-05-06 09:15 - 10:00

In this talk, we address the convergence of the finite element approximation of the minimizer of Freidlin-Wentzell (F-W) action functional. The F-W theory of large deviations is a rigorous mathematical tool to study small-noise-induced transitions in a dynamical system. The central task in the application of F-W theory of large deviations is to seek the minimizer and minimum of the F-W action functional. We discretize the F-W action functional using linear finite element, and establish the convergence of the approximated minimizer through gamma-convergence.

This talk based on a joint work with Xiaoliang Wan(LSU) and Jiayu Zhai(LSU).

3.3.3 Jacobi-like Algorithm for Bethe-Salpeter Eigenvalue Problem (Weiguo Gao)

Weiguo Gao, Fudan University
2017-05-06 10:20 - 11:05

In this talk, we investigate the Bethe-Salpeter eigenvalue problems and propose a Jacobi-like algorithm. The eigen-structure is preserved during the iterations. Global convergence of the new algorithm is given and numerical examples demonstrate the fast convergence.

This is joint-work with Meiyue Shao and Cheming Yang.

3.3.4 Numerical Simulation of Vlasov Equation Using Moment Expansion Method (Yana Di)

Yana Di, Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences
2017-05-06 11:05 - 11:50

A globally hyperbolic moment closer of the Vlasov-Maxwell equations has been derived. The resulting moment equations are computed with fraction step method for time discretization and finite volume discretization for spatial space respectively.

The numerical method has been demonstrated accurate and efficient for the simulations of plasma echo and Landau damping.

3.3.5 High Order Positivity-preserving and Symmetry-preserving Conservative Lagrangian Schemes for Compressible Euler Equations (Juan Cheng)

Juan Cheng, Institute of Applied Physics and Computational Mathematics
2017-05-06 14:00 - 14:45

In applications such as astrophysics and inertial confinement fusion, there are many three-dimensional cylindrical-symmetric multi-material problems which are usually simulated by Lagrangian schemes in the two-dimensional cylindrical coordinates. For this type of simulation, the critical issues for the schemes include keeping positivity of physically positive variables such as density and internal energy and keeping spherical symmetry in the cylindrical coordinate system if the original physical problem has this symmetry. In this talk, we will introduce our recent work on high order positivity-preserving and symmetry-preserving Lagrangian schemes solving compressible Euler equations. The properties of positivity-preserving and symmetry-preserving are proven rigorously. One- and two-dimensional numerical results are provided to verify the designed characteristics of these schemes.

3.3.6 A Nonlinear Finite Volume Scheme for Diffusion Equation on Distorted Meshes (Zhiqiang Sheng)

Zhiqiang Sheng, Institute of Applied Physics and Computational Mathematics
2017-05-06 14:45 - 15:30

In the construction of existing nonlinear cell-centered finite volume schemes preserving positivity, it is required to assume that values of auxiliary unknowns are nonnegative. However, this assumption is not always satisfied. In this talk, we present a new nonlinear finite volume scheme preserving positivity for diffusion equations on distorted meshes. The main feature of the scheme is the assumption that the values of auxiliary unknowns are nonnegative is avoided. Two nonnegative parameters are introduced to define a new nonlinear two-point flux, in which one point is the cell-center and the other is the midpoint of cell-edge. The final flux on the edge is obtained by the continuity of normal flux. Numerical results show that the accuracy of both solution and flux for our new scheme is superior to that of some existing schemes preserving positivity.

3.3.7 The Weak Galerkin Finite element Method for Eigenvalue Problems (Ran Zhang)

Ran Zhang, Jilin University
2017-05-06 15:50 - 16:35

This talk is devoted to studying eigenvalue problem by the weak Galerkin (WG) finite element method with an emphasis on obtaining lower bounds. The WG method uses discontinuous polynomials on polygonal or polyhedral finite element partitions. As such it is more robust and flexible in solving eigenvalue problems since it finds eigenvalue as a min-max of Rayleigh quotient in a larger finite element space. We demonstrate that the WG methods can achieve arbitrary high order convergence. This is in contrast with classical nonconforming finite element methods which can only provide the lower bound approximation by linear elements with only the second order convergence. Numerical results are presented to demonstrate the efficiency and accuracy of the WG method.

This is joint work with Qilong Zhai, Hehu Xie and Zhimin Zhang.

3.3.8 Efficient Algorithm for Nonlocal/Anomalous Models (Jiwei Zhang)

Jiwei Zhang, *Beijing Computational Science and Research Center*
2017-05-06 16:35 - 17:20

This talk has two parts. The first part focuses on the fast evaluation of Caputo fractional derivative and its applications to anomalous diffusion equations. The second part focuses on the design of exact absorbing boundary conditions for nonlocal models, such as nonlocal heat equation, nonlocal Schrodinger equation Some numerical examples are presented to demonstrate the effectiveness of our approach.

3.3.9 Uncertainty Quantification for Linear Transport Equation with Random Inputs (Zheng Ma)

Zheng Ma, *Shanghai Jiao Tong University*
2017-05-06 17:20 - 17:50

In this talk we study the stochastic Galerkin approximation for the linear transport equation with random inputs and diffusive scaling. We first establish uniform (in the Knudsen number) stability results in the random space for the transport equation with uncertain scattering coefficients, and then prove the uniform spectral convergence (and consequently the sharp stochastic Asymptotic-Preserving property) of the stochastic Galerkin method. A micro-macro decomposition based fully discrete scheme is adopted for the problem and proved to have a uniform stability. Numerical experiments are conducted to demonstrate the stability and asymptotic properties of the method.

3.4 2017-05-07

3.4.1 Well-Posedness of Coupled Stokes/Darcy Model with Beavers-Joseph Interface Condition for any Physical Parameters (Yanren Hou)

Yanren Hou, *Xi' an Jiaotong University*
2017-05-07 08:30 - 09:15

In this talk, we consider the well-posedness of the steady-state coupled Stokes/Darcy model with Beavers-Joseph interface condition. By constructing an expanded system, we show that this coupled problem is well-posed for any physical parameters, while some smallness requirement of an experimental determined physical parameter is needed for obtaining the well-posedness of this coupled system in formal literatures.

3.4.2 A New Hydrostatic Reconstruction Scheme Based on Subcell Reconstructions (Guoxian Chen)

Guoxian Chen, *Wuhan University*
2017-05-07 09:15 - 10:00

A key difficulty in the analysis and numerical approximation of the shallow water equations is the non-conservative product of measures due to the gravitational force acting on a sloped bottom. Solutions may be non-unique, and numerical schemes are not only consistent discretizations of the shallow water equations, but they also make a decision how to model the physics. Our derivation is based on a subcell reconstruction using infinitesimal singular layers at the cell boundaries, as inspired by [Noelle, Xing, Shu, JCP 2007]. One key step is to separate the singular measures. Another aspect is the reconstruction of the solution variables in the singular layers. We study three reconstructions. The first leads to the well-known scheme of [Audusse, Bristeau, Bouchut, Klein, Perthame, SISC 2004], which introduces the hydrostatic reconstruction. The second is a modification proposed in [Morales, Castro, Pares, AMC 2013], which analyzes if a wave has enough energy to overcome a step. The third is our new scheme, and borrows its structure from the wet-dry front. For a number of cases discussed in recent years, where water runs down a hill, Audusse's scheme converges slowly or fails. Morales' scheme gives a visible improvement. Both schemes are clearly outperformed by our new scheme.

3.4.3 With or Without de Rham Complex Exact Sequence in FEM in the Computation of Maxwell Equations (Huoyuan Duan)

Huoyuan Duan, *Wuhan University*
2017-05-07 10:20 - 11:05

In this talk, I will address the necessity of the de Rham complex exact sequence in the computation of Maxwell equations by finite element methods. The conclusion is that the exactness of de Rham complex sequence is sufficient for the computation of Maxwell equations. Without this, other finite element methods can work as well. This can be achieved by the different finite element formulations other than the standard ones. Several challenging issues are reviewed. Numerical experiments of nodal-FEMs are presented.

3.4.4 Fully Diagonalized Chebyshev and Legendre Spectral Methods (Zhongqing Wang)

Zhongqing Wang, University of Shanghai for Science and Technology
2017-05-07 11:05 - 11:50

Fully diagonalized Chebyshev and Legendre spectral methods for solving second and fourth order elliptic boundary value problems are proposed. They are based on appropriate base functions for the Galerkin formulations which are complete and orthogonal/biorthogonal with respect to certain Sobolev inner product. The suggested base functions lead to diagonalization of discrete systems. Accordingly, both the exact solutions and the approximate solutions can be represented as infinite and truncated Fourier series. Numerical results demonstrate the effectiveness and the spectral accuracy.