中国科学院深圳先进技术研究院

Shenzhen Institutes of Advanced Technology,Chinese Academy of Sciences

深圳市计算与应用数学研讨会

Shenzhen Workshop on Computational and Applied Mathematics

会议手册

中国·深圳

2021 年 6 月 18 日—2021 年 6 月 21 日

主办单位：深圳市数学科普学会

承办单位：中国科学院深圳先进技术研究院


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中国科学院深圳先进技术研究院
Shenzhen Institutes of Advanced Technology,Chinese Academy of Sciences

会议信息

计算与应用数学的研究目前是国内外数学研究领域比较前沿和热点的课题。为了促进计算与应用数学研究领域的学术交流与合作，了解计算与应用数学各分支领域的最新研究动态，拟定于 2021 年 6 月 18 至 21 日在深圳市南山万科云城亚朵酒店举行深圳市计算与应用数学研讨会。

此次将邀请深圳市及其周边计算与应用数学领域的专家学者与会交流，深入探讨计算与应用数学领域所面临的机遇、挑战和未来发展方向，以推动学科的发展和进步，促进计算与应用数学研究领域学者的学术交流与合作。

欢迎各位同仁踊跃参加本次学术会议。

会议学术委员会成员：（拼音字母为序）

王晓明（主席）	南方科技大学
陈荣亮	中国科学院深圳先进技术研究院
李景治	南方科技大学
张晔	深圳北理莫斯科大学

组织委员会成员：（拼音字母为序）

陈荣亮	中国科学院深圳先进技术研究院
闫争争	中国科学院深圳先进技术研究院
林增	中国科学院深圳先进技术研究院

会务组联系人：

曹耀明	caoym@mail.sustech.edu.cn	13940254925
杨志鹏	yangzp2020@mail.sustech.edu.cn	19520586397


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会议指南

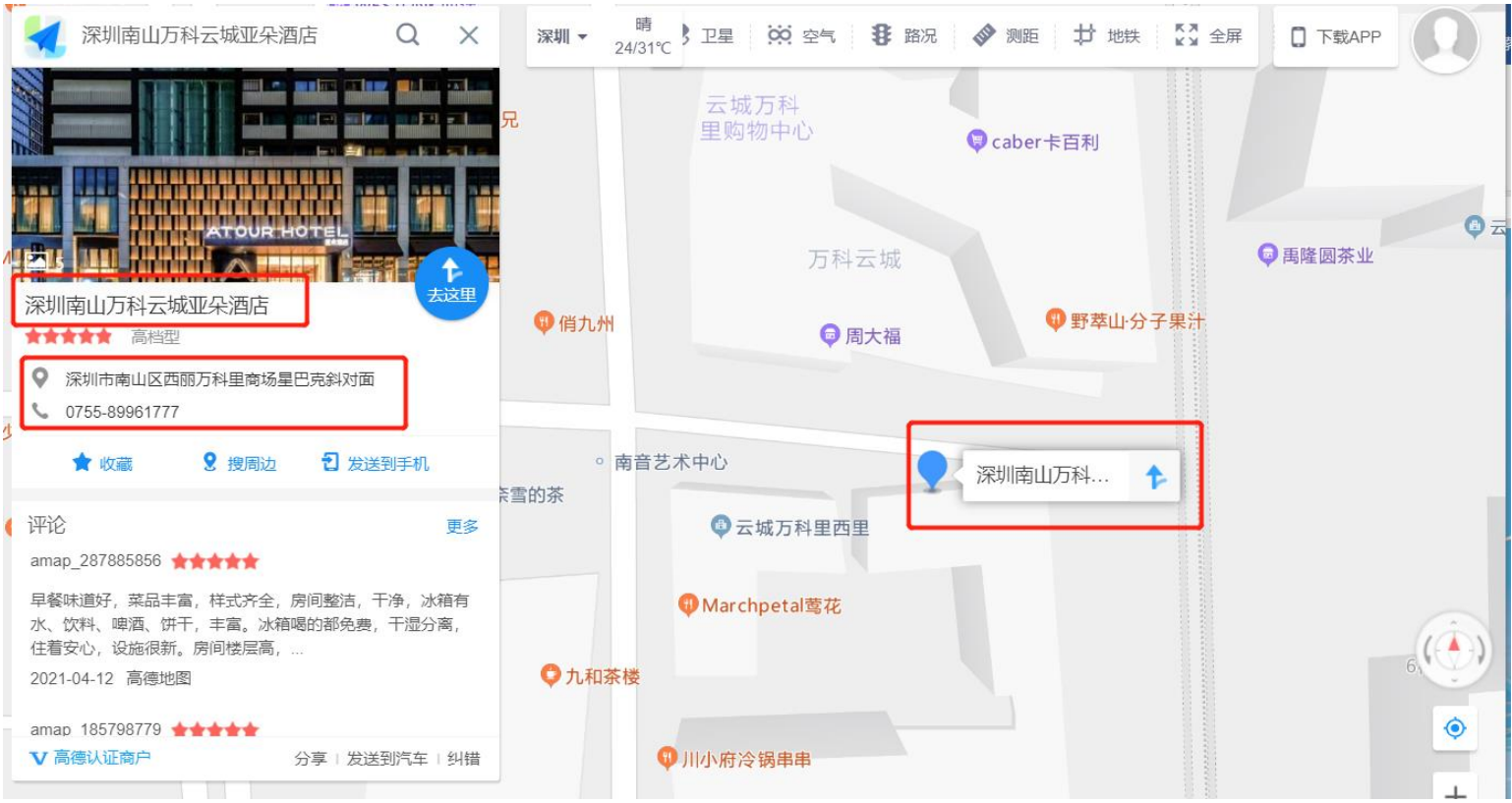
一、会议报到：

报到时间：2021 年 6 月 18 日（9:00 am-18:00pm）

报到地点：深圳市南山万科云城亚朵酒店（见下图）

酒店前台电话：0755-89961777

深圳市南山区西丽万科里商场星巴克斜对面



二、会议地点

由于疫情影响，会议采用线下+线上方式进行。

- 线下会议地点：深圳市南山万科云城亚朵酒店

- 线上会议通过腾讯会议进行。点击链接入会，或添加至会议列表：

  https://meeting.tencent.com/s/PMtATvVSC6bX

  会议 ID：825 607 537

  会议密码：210619

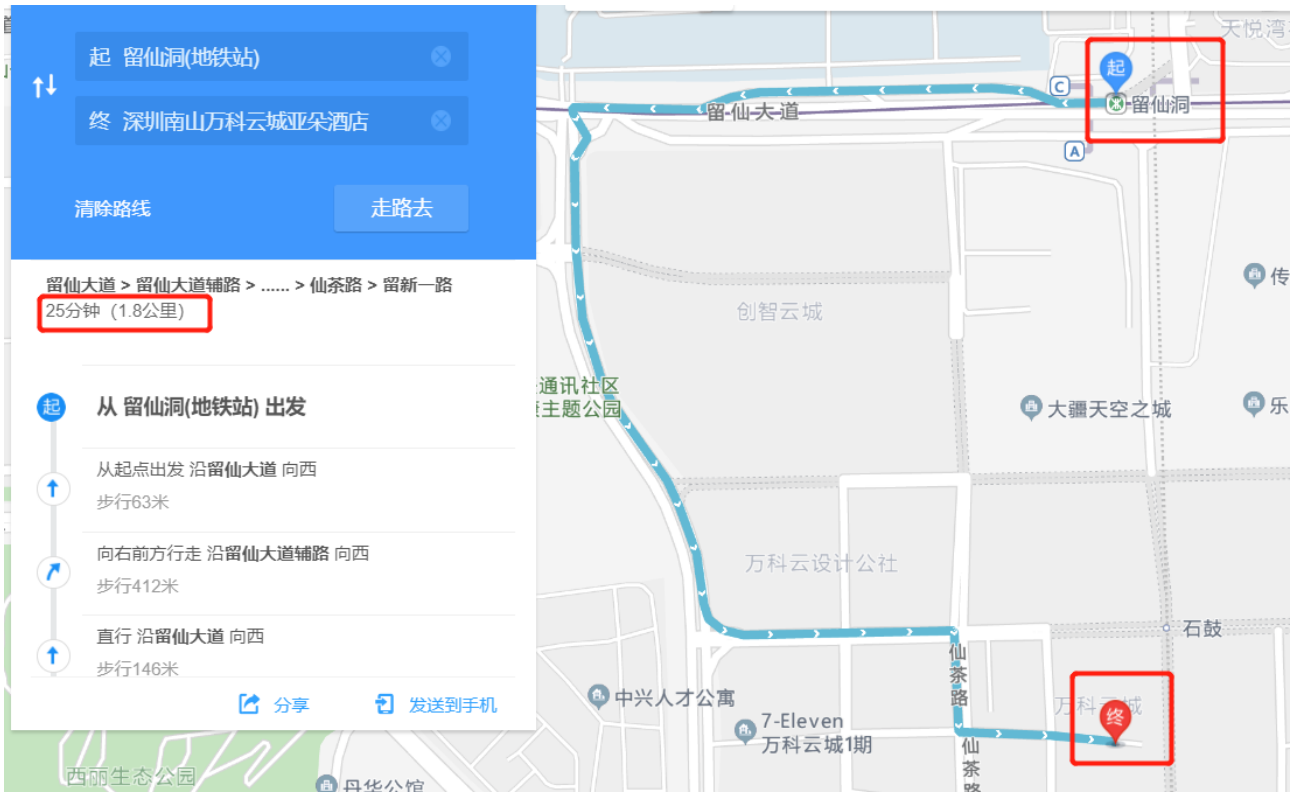
三、交通指引：

1）打车或者自驾

请导航深圳市南山万科云城亚朵酒店

2）乘坐地铁

请在留仙洞地铁站 A 口出站，之后大约步行 25 分钟，步行路线请见如下示意图。



会议日程

时间		活动内容	地点
6 月 18 日	08：00—22：00	会议报到	深圳市南山万科云城亚朵酒店
	18：00	晚餐	深圳市南山万科云城亚朵酒店
6 月 19 日	09：00—11：30	学术报告	深圳市南山万科云城亚朵酒店
	12：00—14：00	午餐	深圳市南山万科云城亚朵酒店
	14：00—17：40	学术报告	深圳市南山万科云城亚朵酒店
	18:00	欢迎晚宴	深圳市南山万科云城亚朵酒店
6 月 20 日	09：00—11：30	学术报告	深圳市南山万科云城亚朵酒店
	12：00—14：00	午餐	深圳市南山万科云城亚朵酒店
	14：00—17：40	学术报告	深圳市南山万科云城亚朵酒店
	18：00	晚餐	深圳市南山万科云城亚朵酒店
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	14：00—17：40	学术报告	深圳市南山万科云城亚朵酒店
	18：00	晚餐	深圳市南山万科云城亚朵酒店

会议报告安排

6 月 19 日　深圳市南山万科云城亚朵酒店 腾讯会议链接：　https://meeting.tencent.com/s/PMtATvVSC6bX 会议 ID：825 607 537　　会议密码：210619			
时间	报告人	题目	主持人
09:00—10:00	涂家礼	主动脉夹层基于流固耦合的血流动力学模拟	王超
10:00—10:30　　茶歇			
10:30—11:30	龙海娥	求解非线性反问题的 Nesterov 型加速算法研究	王超
11:30—14:00　　午餐			
14:00—15:00	闫争争	Influence of coronary revascularization procedures on cerebral hemodynamics	王超
15:00—15:30　　茶歇			
15:30—16:30	D. Chaikovskii	Application of asymptotic methods to forward and inverse problems in PDEs	王超
16:40—17:40	黄沁	A new second order dynamic method for solving linear inverse problems in Hilbert spaces	王超

6 月 20 日　深圳市南山万科云城亚朵酒店 腾讯会议链接：　https://meeting.tencent.com/s/PMtATvVSC6bX 会议 ID：825 607 537　　会议密码：210619			
时间	报告人	题目	主持人
09:00—10:00	张文龙	The applications of empirical process in the uncertainty quantification driven by PDE problems with observational data	杨志鹏
10:00—10:30　　茶歇			
10:30—11:30	徐晨	Estimating the memory parameter for possibly non-linear and non-Gaussian time series with wavelets	杨志鹏
11:30—14:00　　午餐			
14:00—15:00	田伟	A Parallel Domain Decomposition Preconditioner for Elastic Crack Simulation Using XFEM	杨志鹏
15:00—15:30　　茶歇			
15:30—16:30	杨建勋	关于瑞利面波频散正问题的研究	杨志鹏
16:40—17:40	杨志鹏	Bayesian Approach to Inverse Time-harmonic Acoustic Obstacle Scattering with Phaseless Data Generated by Point Source Waves	杨志鹏

6 月 21 日　深圳市南山万科云城亚朵酒店 腾讯会议链接：　https://meeting.tencent.com/s/PMtATvVSC6bX 会议 ID：825 607 537　　会议密码：210619			
时间	报告人	题目	主持人
09:00—10:00	古林燕	Decomposition and Preconditioning of Deep Convolutional Neural Networks for Training Acceleration	杨志鹏
10:00—10:30　　茶歇			
10:30—11:30	常钰佳	人体心脏基于流固耦合的力学分析	杨志鹏
11:30—14:00　　午餐			
14:00—15:00	蒋毅	Numerical Survey On Cardiac Elasticity Simulations in Parallel Environment	杨志鹏
15:00—15:30　　茶歇			
15:30—16:30	徐磊	Parallel finite-volume discrete Boltzmann method for inviscid compressible flows on unstructured grids	杨志鹏
16:40—17:40	王超	A Mixed Finite Element Scheme for Maxwell's Transmission Eigenvalue Problem	杨志鹏

会议摘要

Application of asymptotic methods to forward and inverse problems in PDEs

D. Chaikovskii

深圳北理莫斯科大学

Abstract: In this talk, by employing the asymptotic method, we prove the existence and uniqueness of smoothing solutions for a singularly perturbed partial differential equation (PDE) with a small parameter. As a by-product, we obtain a reduced PDE model with vanished high order derivative terms, which is close to the original PDE model in any order of this small parameter in the whole domain except a negligible transition layer. Based on this reduced forward model, we propose an efficient two step regularization algorithm for solving inverse source problems governed by the original PDE. Convergence rate results are studied for the proposed regularization algorithm, which shows that this simplification will not (asymptotically) decrease the accuracy of the inversion result when the measurement data contains noise. Numerical examples for both forward and inverse problems are given to show the efficiency of the proposed numerical approach.

主动脉夹层基于流固耦合的血流动力学模拟

涂家礼

中国科学院深圳先进技术研究院

Abstract: 主动脉夹层是指由主动脉壁内膜撕裂，导致血液进入主动脉壁内部，形成新的流通通道的一种心血管疾病。在主动脉夹层的发展和治疗过程中，血流动力学因素有着重要的参考价值。基于血流动力学的数值模拟方法，能够为临床诊疗提供更多重要的诊断和预后信息，从而降低或者规避手术风险。

主动脉夹层血流动力学模拟经历了从刚性壁到流固耦合模型、理想几何模型到复杂几何模型的发展，模型复杂度提升的同时也使得计算成本急剧增加，三维主动脉夹层流固耦合模拟时间通常高达几百个小时，严重影响了模拟的实际应用价值。为了能够快速的实现三维主动脉夹层流固耦合问题的高精度模拟，本文采用一种基于超级计算机的并行模拟方法。在我们的研究中，整个数学模型包含基于任意的拉格朗日欧拉描述的瞬态流体力学方程，以及基于拉格朗日描述的固体力学方程和网格移动方程。所有方程被耦合到一个全耦合系统中进行离散求解。在

对大规模的全耦合系统离散过程中，我们采用了基于非结构化网格的有限元空间离散和基于有限差分的全隐式时间离散方法；最后采用基于区域分解算法的并行 Newton-Krylov-Schwarz 算法对每个时间步中的大规模非线性系统进行求解。

我们对一个真实的主动脉夹层病例进行了快速、高精度的数值模拟，数值结果表明，流固耦合模型相对刚性壁模型能够识别更多的血流动力学信息，模拟所得到的压力、速度、壁面剪切力和主动脉壁的位移都在一个合理的生理范围。此外，本文利用 Tianhe-2A 超级计算机对算法进行了可扩展性测试，其中刚性壁模型在 3840 核时，效率达到 40.25%；流固耦合模型在 2304 核也能保证 44.15% 的并行效率。本文提出的方法能够对千万量级网格单元的主动脉夹层流固耦合问题，求解器在一小时之内可完成一个完整心跳周期的高精度模型，因而具有很强的临床应用潜能。

Determining a random Schrödinger operator: both potential and source are random

李景治

南方科技大学

Abstract: We present an inverse scattering problem associated with a Schrödinger system where both the potential and source terms are random and unknown. The well-posedness of the forward scattering problem is first established in a proper sense. We then derive two unique recovery results in determining the rough strengths of the random source and the random potential, by using the corresponding far-field data. The first recovery result shows that a single realization of the passive scattering measurements uniquely recovers the rough strength of the random source. The second one shows that, by a single realization of the backscattering data, the rough strength of the random potential can be recovered. The ergodicity is used to establish the single realization recovery. The asymptotic arguments in our study are based on techniques from theory of pseudodifferential operators and microlocal analysis.

High Performance Blood Flow Simulation Algorithms and Applications

陈荣亮

中国科学院深圳先进技术研究院

Abstract: Image data is able to provide increasingly detailed information of anatomy and flow, but imaging alone is not a predictive tool. Patient-specific blood flow simulations have the potential to provide quantitative predictive tools for virtual surgery, treatment planning, and risk stratification. To accurately resolve the blood flows based on the patient-specific geometry and parameters is still a big challenge because of the complex geometry and the turbulence, and it is also important to obtain the results in a short amount of computing time so that the simulation can be used in surgery planning. In this talk, we will discuss some scalable parallel methods for the simulation of blood flow in compliant arteries on large scale supercomputers. The blood flow is modeled by 3D unsteady incompressible Navier-Stokes equations with a lumped parameter boundary condition, which are discretized with a stabilized finite element based on unstructured meshes in space and a fully implicit method in time. The large scale discretized nonlinear systems are solved by a parallel Newton-Krylov method preconditioned by linear and nonlinear domain decomposition preconditioners. Numerical results show that the proposed methods work well for realistic geometry and parameters on a supercomputers with thousands of processor cores. A patient-specific analysis, with a resolution higher than 4D MRI can be obtained in less than one hour.

The applications of empirical process in the uncertainty quantification driven by PDE problems with observational data

张文龙

南方科技大学

Abstract: For many real applications, the data needed for computation is mixed by random noise or random field, this is the so called uncertainty quantification(UQ). In this talk, I will show some new reasearch in the uncertainty quantification driven by PDE problems including theory and numerical examples. The observational data in practice is always blurred by some noise, e.g. natural noise, the error of the measurements and the error of the model itself. For years, it's a chanllenge to recover the true information from noisy data in many fileds. In this talk I will give new analytical tools to estimate the stochastic convergence in some problems driven by PDE using regularization method. It

provides the optimal parameter choices in the models and the stochastic error estimates are given therein. Several applications will be shown in this talk.

A Parallel Domain Decomposition Preconditioner for Elastic Crack Simulation Using XFEM

田伟

中国科学院深圳先进技术研究院

Abstract: We study a parallel overlapping domain decomposition preconditioner for solving the linear system of equations arising from the extended finite element discretization of elastic crack problems. The algorithm partitions the computational mesh into two types of subdomains: the regular subdomains and the crack tip subdomains, based on the observation that the crack tips have a big impact on the number of iterations, but the impact of the crack lines is not that different from the regular mesh points. The tip subdomains consist of mesh points at crack tips and all neighboring points where the branch enrichment functions are applied, and the regular subdomains consist of all other mesh points including these on the crack lines. Following the Schwarz framework, an overlapping region is added to all subdomains. Numerical experiments indicate that the proposed method reduces the number of iterations and the total compute time significantly compared with the classical method. Moreover, the method scales up to 8192 processor cores with above 70\% parallel efficiency for problems with more than 2×10^8 degrees of freedom.

人体心脏基于流固耦合的力学分析

常钰佳

中国科学院深圳先进技术研究院

Abstract: 心脏是人体血流循环的动力源，其生物力学参数是心脏的功能性能评估，心脏疾病的病理研究、预测和诊断的重要指标。本文利用自主研发的一套并行算法针对人体心脏左心室的血流动力学进行数值仿真和力学分析。该方法首先基于人体心脏的 CT 医学影像数据重构获

得左心室的三维几何结构并建立描述心肌和血液的流固耦合数学模型，然后对该三维结构（包括心肌和腔室）生成非结构的四面体网格并对相应的数学模型进行离散求解。在数学模型上，我们采用三维非稳态不可压缩 Navier-Stokes 方程来描述血液的流动，线弹性方程刻画固体的形变，然后通过速度和压力界面条件来传递血流和心肌的相互作用。在求解算法上，本文采用一阶的有限元方法和全隐的向后欧拉差分格式分别在空间和时间方向对数学模型进行离散，然后利用并行 Newton-Krylov-Schwarz 算法求解每个时间步中的非线性方程组获得相应的力学参数。数值实验显示，通过与临床影像数据的对比，数值仿真结果可以准确刻画左心室心肌组织和其内含血液的动态力学细节特征。此外，该算法对本文所研究的流固耦合问题具有很好的稳定性和鲁棒性，且该算法扩展到 2300 个计算核心时仍然有 40%的并行效率，这表明该算法具有使用大型超级计算机对人体心脏血流动力学进行精细快速模拟分析的能力。.

Influence of coronary revascularization procedures on cerebral hemodynamics

闫争争

中国科学院深圳先进技术研究院

Abstract: Coronary artery stenting has been the common minimally invasive technologies for coronary artery disease (CAD) caused by coronary artery stenosis. The procedure can improve the cardiac hemodynamics by modifying the vascular anatomy, and subsequently improve myocardial blood supply. However, during coronary revascularization, some patients will be accompanied by life-threatening strokes, even if patient's cerebrovascular has no obvious stenosis. Therefore, clinicians are frequently called upon to assess patients with cerebral complications from the procedure. Ethical restrictions, physiological complexity, and lack of monitoring methods make clinical evaluation difficult. In this work, we study the effect of the coronary revascularization on cerebral hemodynamics by artificially adding/eliminating coronary geometric stenosis. A scalable domain decomposition-based algorithm is applied for solving the pulsating cardiovascular and cerebrovascular blood flow. Numerical results show that although the coronary revascularization can improve the functional index of coronary Fractional Flow Reserve (FFR), but it will reduce the functional index of cerebral blood flow Fractional Pressure Ratio(FPR), which may cause stroke. We will present the parallel performance of the algorithm with a large number of processor cores.

Decomposition and Preconditioning of Deep Convolutional Neural Networks for Training Acceleration

古林燕

中国科学院深圳先进技术研究院

Abstract: Deep convolutional neural networks (DCNNs) have led to significant breakthroughs with large neural networks and large datasets; however, larger net- works and larger datasets result in longer training times. In this paper, a new approach of decomposing and preconditioning DCNNs is proposed to parallelize the training of DCNNs. First, following the idea of domain decomposition methods, a global network is decomposed into several sub-networks by partitioning the width of the network while keeping the depth constant, which are then individually trained in parallel with the corresponding decomposed samples from the input data. Then, inspired by the nonlinear preconditioning method, the trained sub-networks are recomposed to initialize the global network, which we call the sub-network transfer learning strategy. The initialized global network is then further trained. At last, some experiments show that the sub-network transfer learning strategy can indeed provide good initialization and accelerate the training of the global network with no loss of accuracy.

Bayesian Approach to Inverse Time-harmonic Acoustic Obstacle Scattering with Phaseless Data Generated by Point Source Waves

杨志鹏

南方科技大学

Abstract: This talk concerns the Bayesian approach to inverse acoustic scattering problems of inferring the position and shape of a sound-soft obstacle from phaseless far-field data generated by two-dimensional point source waves. Given the total number of obstacle parameters, the Markov chain Monte Carlo (MCMC) method is employed to reconstruct the boundary of the obstacle in a high-dimensional space, which usually leads to slow convergence and prohibitively high computational cost. We use the Gibbs sampling and preconditioned Crank-Nicolson (pCN) algorithm with random proposal variance to improve the convergence rate, and design an effective strategy for the surrogate model constructed by the generalized polynomial chaos (gPC) method to reduce the computational cost of MCMC.

Parallel finite-volume discrete Boltzmann method for inviscid compressible flows on unstructured grids

徐磊

中国科学院深圳先进技术研究院

Abstract: In this talk, a finite-volume discrete Boltzmann method based on a cell-centered scheme for inviscid compressible flows on unstructured grids is presented. In the new method, the equilibrium distribution functions are obtained from the circle function in two-dimensions (2D) and the spherical function in three-dimensions (3D). Moreover, the advective fluxes are evaluated by Roe's flux-difference splitting scheme, the gradients of the density and total energy distribution functions are computed with a least-squares method, and the Venkatakrishnan limiter is employed to prevent oscillations. To parallelize the method we use a graph-based partitioning approach that also guarantees the load balancing. The method is validated by seven benchmark problems: (a) a 2D flow pasting a bump, (b) a 2D Riemann problem, (c) a 2D flow passing the RAE2822 airfoil, (d) flows passing the NACA0012 airfoil, (e) 2D supersonic flows around a cylinder, (f) an explosion in a 3D box, and (g) a 3D flow around the ONERA M6 wing. The benchmark tests show that the results obtained by the proposed method match well with the published results, and the parallel numerical experiments show that the proposed parallel implementation has close to linear strong scalability, and parallel efficiencies of 95.31% and 94.56% are achieved for 2D and 3D problems on a supercomputer with up to 4800 processor cores, respectively.

Numerical Survey On Cardiac Elasticity Simulations in Parallel Environment

蒋毅

中国科学院深圳先进技术研究院

Abstract: Cardiac function is fulfilled by the periodic systolic and dystolic deformation of the heart muscles, which, in a mechanical point of view, can be described by the theory of hyper elasticity. In this talk, we propose a highly efficient numerical method for simulating the cardiac elastodynamics, and investigate the performances of the numerical solver that is built based the finite element method.

求解非线性反问题的 Nesterov 型加速算法研究

龙海娥

深圳北理莫斯科大学

Abstract: 在 Hilbert 空间中针对包含多个非线性不适定算子方程的大规模问题，结合 Kaczmarz 加速策略和 Nesterov 加速格式的推广形式，提出了几类快速有效的迭代方法，并结合适当的停止准则分析了它们的收敛性和正则性。进而将所提出的方法应用于椭圆参数识别和扩散光学层析成像问题验证了它们的有效性和加速效果。此外，针对非光滑非线性反问题，引入 Bouligand 次微分和推广形式的 Nesterov 加速格式，构造了 Nesterov 型加速 Bouligand-Landweber 迭代格式。理论上给出了方法的收敛性和正则性分析，并通过数值模拟展示了其显著的加速效果。

A new second order dynamic method for solving linear inverse problems in Hilbert spaces

黄沁

北京理工大学

Abstract: In this paper, a new second order dynamic method (SODM) is proposed for solving ill-posed linear inverse problems in Hilbert spaces. The SODM can be viewed as a combination of Tikhonov regularization and second order asymptotical regularization methods, where time dependent regularization parameter is used. A convergence result when the noisy level goes to zeros is shown. With time discretization, and for different choice of damping parameters, several iterative schemes are proposed. The relaxed discrepancy principle is applied for the stop criterion. A series of numerical experiments are implemented. As shown by numerical results, compared with classical Tikhonov methods and the first order dynamical system method, on the whole, the new method leads to more accurate approximate solutions while requires less iterative number which indicates that the proposed SODM is feasible and effective.

Estimating the memory parameter for possibly non-linear and non-Gaussian time series with wavelets

徐晨

深圳北理莫斯科大学

Abstract: The asymptotic theory for the memory parameter estimator constructed from log-regression with wavelets is incomplete for 1/f processes that are not necessarily Gaussian or linear. Such a theory is necessary due to the importance of non-Gaussian and nonlinear long memory models in describing financial time series. To fill this gap, we prove that under an assumption which can be implied by ergodicity and additional ones, the estimator is asymptotically consistent.

关于瑞利面波频散正问题的研究

杨建勋

深圳北理莫斯科大学

Abstract: 本文推导了一种计算各向同性层状介质中瑞利面波相速度的方法。在应力张量中引入了“阻抗张量”系数获得了瑞利面波频散方程新迭代关系。该方法能在低频区（0.5-80s）进行对频散方程进行快速求解，并具有较好的稳定性和准确性。且在含有低速层的介质模型时也能很好的进行相速度的计算。数值模拟结果表明，该方法适用于天然地震中瑞利面波的正反演问题，即利用测量的瑞利波频散曲线反演地壳或上地幔的 S 波速度结构，并对其结果进行相关地球物理学的解释。

A Mixed Finite Element Scheme for Maxwell's Transmission Eigenvalue Problem

王超

南方科技大学

Abstract: We present a new mixed finite element scheme using N\'ed\'elec edge elements to approximate both the solution and its curl for the Maxwell's transmission eigenvalue problem. We impose element-wise stabilization instead of stabilization along mesh interfaces. Thus our scheme can be implemented as easy as standard N\'ed\'elec methods for Maxwell's equations. Through a discrete energy norm stability due to element-wise stabilization, we prove optimal convergence under a low regularity condition.
