2023 International Conference on Numerical Methods and Applications and 4th Fujian Province Annual Conference on Computational Mathematics

2023年数值方法及应用国际会议暨第四届福建省计算数学年会

会 议 手 册

福建师范大学数学与统计学院
分析数学及应用教育部重点实验室
福建省高校数学学科联盟

2023年11月3日-5日 | 福建·福州

目录

01 会议概览

主　　题　2023 年数值方法及应用国际会议暨第四届福建省计算数学年会

时　　间　2023 年 11 月 3 日-5 日

会议地点　福州旗山梅园酒店（地址: 福建省福州市闽侯县国宾大道 350 号）

主办单位　福建师范大学数学与统计学院

分析数学及应用教育部重点实验室

福建省高校数学学科联盟

承办单位　福建师范大学数学与统计学院

会议特邀专家（按姓氏字母顺序排列）

王立联　　新加坡南洋理工大学

田方宝　　澳大利亚新南威尔士大学

闫玉斌　　英国切斯特大学

洪佳林　　中国科学院数学与系统科学研究院

费林林　　瑞士苏黎世联邦理工学院

组织委员会主席

许传炬　王美清　赖惠林

组织委员会成员

陈黄鑫　李娴娟　柯艺芬　王晓峰　梁宗旗　詹华税　庄清渠　谢亚君　曾闽丽　滕忠铭　闫同新

会议联系人

赖惠林 13599964053　　柯艺芬 18050434368

02 会议简介

为促进福建省高校和研究机构计算数学工作者的学术交流与合作，福建师范大学将于2023年11月3日至5日举办“2023年数值方法及应用国际会议暨第四届福建省计算数学年会”。

本次会议旨在为来自计算数学不同领域的专家提供一个交流平台，会议主题涵盖计算数学及交叉学科和大数据应用相关的数学理论和方法。欢迎相关领域专家、学者及研究生参会交流。

历届福建省计算数学年会

第一届，2017年12月15日-16日，厦门大学

第二届，2019年12月6日-8日，福州大学

第三届，2021年12月3日-5日，闽南师范大学

03 学术报告日程安排

11 月 3 日，星期五下午，福州旗山梅园酒店			
14:00-21:00	报到注册，福州旗山梅园酒店一楼大堂		
18:00-21:00	晚餐，福州旗山梅园酒店 F 楼茶餐厅自助餐		
11 月 4 日，星期六上午，福州旗山梅园酒店二楼 B 厅			
8:00-8:30	开幕式（合影）	福建师范大学数学与统计学院院长王健教授致辞 会议组委会主席厦门大学许传炬教授致辞	
报告时间	**报告人**	**报告题目**	**主持人**
8:30-9:10	王立联 新加坡南洋理工大学	Spectral Methods: Some Recent Advances and New Perspectives	许传炬 厦门大学
9:10-9:50	洪佳林 中国科学院数学与系统科学研究院	Stochastic Symplectic Methods of Stochastic Hamiltonian Systems	
9:50-10:10	茶歇		
10:10-10:30	王晓峰 闽南师范大学	几类非线性方程高精度差分格式	马昌凤 福建师范大学
10:30-10:50	柯艺芬 福建师范大学	Quasi Non-Negative Quaternion Matrix Factorization with Application to Color Face Recognition	
10:50-11:10	黄灿 厦门大学	Fully discretization schemes for the stochastic Stokes-Darcy equations	
11:10-11:30	曾莉 福州大学	Deep adaptive density approximation for Fokker-Planck type equations	王美清 福州大学
11:30-11:50	占青义 福建农林大学	Symplectic numerical integration for Hamiltonian stochastic differential equations with multiplicative Lévy noise in the sense of Marcus	
11:50-12:10	熊美馨 福建理工大学	Pre-classification based stochastic reduced-order model for time-dependent complex system	
12:10-13:00	午餐，福州旗山梅园酒店 F 楼茶餐厅自助餐		
11 月 4 日，星期六下午，福州旗山梅园酒店二楼 B 厅			

14:00-14:40	费林林 瑞士苏黎世联邦理工学院	Coupled LBM-DEM model for gas-liquid -solid interaction problems（线上）	赖惠林 福建师范大学
14:40-15:00	翟术英 华侨大学	A high order operator splitting method for the nonlocal phase-field model	
15:00-15:20	黄宝华 福建师范大学	A smoothing Newton method based on the modulus equation for a class of weakly nonlinear complementarity problem	王晓峰 闽南师范大学
15:20-15:40	黄少武 莆田学院	A new view of a result on the doubly superstochastic matrices	
15:40-16:00	牛晓花 厦门理工学院	耦合自攀移的棱柱位错环攀移的相场模型	
16:00-16:20	茶歇		
16:20-17:00	闫玉斌 英国切斯特大学	Unconditionally stable and convergent difference scheme for superdiffusion with extrapolation（线上）	邱建贤 厦门大学
17:00-17:15	王未文 北京师范大学	Arbitrarily high order time-stepping method for the anisotropic phase-field dendritic crystal growth model	
17:15-17:30	胡晶晶 福建师范大学	Efficient iterative method for generalized Sylvester quaternion tensor equation	柯艺芬 福建师范大学
17:30-17:45	向亚红 厦门大学	Stabilized variational formulations of Chorin-type and artificial compressibility methods for the stochastic Stokes-Darcy equations	
17:45-18:00	陈乾泰 福州大学	基于图神经网络的动作时序定位模型	
18:00-18:15	刘鑫源 厦门大学	High order positivity-preserving nodal discontinuous Galerkin methods for anisotropic diffusion problems	
18:15-20:00	晚餐，福州旗山梅园酒店二楼宴会 C 厅		
11 月 5 日，星期日上午，福州旗山梅园酒店二楼 B 厅			
8:00-8:40	田方宝 澳大利亚新南威尔士大学	An immersed boundary-lattice Boltzmann method for fluid-structure interactions involving viscoelastic fluids（线上）	陈黄鑫 厦门大学
8:40-8:55	郑少钦	High order conservative LDG-IMEX methods	

	厦门大学	for the degenerate nonlinear non-equilibrium radiation diffusion problems	
8:55-9:10	郭亚瑜 厦门大学	High order reduced basis for the Allen-Cahn equation	李娴娟 福州大学
9:10-9:25	蔡超仪 厦门大学	相对论流体力学的保物理还原原始变量算法	
9:25-9:40	何育宇 厦门大学	Stability and Error Analysis of SAV Schemes for Electrohydrodynamic Model with Variable Density	
9:40-9:55	许永亮 福州大学	云存储中基于区块链的数据完整性审计	
9:55-10:15	茶歇		
10:15-10:30	吴峴 厦门大学	多介质流问题的应用子单元限制器的间断 Galerkin 格式	梁宗旗 集美大学
10:30-10:45	王方 厦门大学	On Krylov subspace methods for skew-symmetric and shifted skew-symmetric linear systems	
10:45-11:00	王志好 厦门大学	Kirchhoff-Love shell representation and analysis using triangle configuration B-splines	
11:00-11:15	董飘飘 厦门大学	Prediction-correction threshold dynamics method for topology optimization of steady-state heat transfer problems	
11:15-11:30	翁咏佳 厦门大学	Global optimization of optimal Delaunay triangulation with modified whale optimization algorithm	谢亚君 福州外语外贸学院
11:30-11:45	黄振威 厦门大学	An increasing rank Riemannian method for generalized Lyapunov equations	
11:45-12:00	林斌 厦门大学	Neural Operator Learning Enhanced Physics-informed Neural Networks for solving differential equations with sharp solutions	
12:00-12:10	闭幕式		
12:10-13:30	午餐，福州旗山梅园酒店 F 楼茶餐厅自助餐		
11 月 5 日，星期日下午自由讨论			

04 学术报告题目及摘要

（按报告时间顺序排列）

1. Spectral Methods: Some Recent Advances and New Perspectives

王立联 教授 新加坡南洋理工大学

摘要： In the past decades, the spectral method has become one of the major tools in scientific computing due to its superior accuracy and efficiency when it is properly designed. In this talk, we shall review the evolution of spectral method and elaborate on some recent advancements from the perspective of (i) Singular, fractional and nonlocal problems; (ii) Complex domains/geometries (e.g., spectral fictitious domain method and spectral methods on pipes, knots etc); and (iii) PDEs with highly oscillatory solutions among others. We shall also outline some new directions that the spectral method can excel itself and unknown areas that the spectral method might be the method of choice.

2. Stochastic Symplectic Methods of Stochastic Hamiltonian Systems

洪佳林 研究员 中国科学院数学与系统科学研究院

摘要： Plenty of numerical experiments show that stochastic symplectic methods are superior to non-symplectic ones especially in long-time computation, when applied to stochastic Hamiltonian systems. In this talk we first review some basic results on stochastic symplectic methods of stochastic Hamiltonian systems, such as the theory of stochastic generating functions, variational integrators, pseudo-symplectic methods, etc. Then we present the probabilistic superiority of stochastic symplectic methods of stochastic Hamiltonian systems via large deviations principle. (In collaboration with Dr. Chuchu Chen, Dr. Diancong Jin and Dr. Liying Sun).

3. 几类非线性方程高精度差分格式

王晓峰 教授 闽南师范大学

摘要： 自然界中许多的现象本质上是非线性的, 所以非线性现象引起了工程师、物理学家、数学家和许多其他领域的科学家的兴趣、关注. 很大一部分非线性现象可以用非线性偏微分方程来描述. 然而绝大多数数值方法收敛精度低、效率慢等, 无法满足实际工程应用中. 本报告对几非线性方程建立高精度数值算法，研究格式解的唯一性、保结构性（守恒性、耗散性等）、收敛性、稳定性等性质.

4. Quasi Non-Negative Quaternion Matrix Factorization with Application to Color Face Recognition

柯艺芬 副研究员 福建师范大学

摘要： To address the non-negativity dropout problem of quaternion models, a novel quasi non-negative quaternion matrix factorization (QNQMF) model is presented for color image processing. To implement QNQMF, the quaternion projected gradient algorithm and the quaternion alternating

direction method of multipliers are proposed via formulating QNQMF as the non-convex constraint quaternion optimization problems. Some properties of the proposed algorithms are studied. The numerical experiments on the color image reconstruction show that these algorithms encoded on the quaternion perform better than these algorithms encoded on the red, green and blue channels. Furthermore, we apply the proposed algorithms to the color face recognition. Numerical results indicate that the accuracy rate of face recognition on the quaternion model is better than on the red, green and blue channels of color image as well as single channel of gray level images for the same data, when large facial expressions and shooting angle variations are presented.

5. Fully discretization schemes for the stochastic Stokes-Darcy equations

黄灿 副教授 厦门大学

摘要： In this talk, I will present two numerical schemes and their convergence analysis for the stochastic Stokes-Darcy equations with multiplicative noise. Fully implicit Euler scheme and artificially compressibility method (ACM) scheme are used individually for time discretization. IPDG scheme based on the BDM1-P0 finite element is used for the space discretization. It is proved that both schemes are unconditionally stable and convergence analysis is also available for the first scheme.

6. Deep adaptive density approximation for Fokker-Planck type equations

曾莉 副教授 福州大学

摘要： In recent years, deep learning algorithms based on deep neural networks have been widely applied to solving high-dimensional partial differential equations, which include physics-informed neural networks (PINNs), Deep Ritz method, and so on. In this talk, we start from Fokker-Planck equations and propose flow-based adaptive sampling strategies to improve the efficiency and accuracy of PINNs for solving partial differential equations whose solutions are probability density functions.

7. Symplectic numerical integration for Hamiltonian stochastic differential equations with multiplicative Lévy noise in the sense of Marcus

占青义 副教授 福建农林大学

摘要： In this paper, we propose a symplectic numerical integration method for a class of Hamiltonian stochastic differential equations with multiplicative Lévy noise in the sense of Marcus. We first construct a general symplectic Euler scheme for these equations, then we prove its convergence. In addition, we provide realizable numerical implementations for the proposed symplectic Euler scheme in detail. Some numerical experiments are conducted to demonstrate the effectiveness and superiority of the proposed method by the simulations of its orbits, Hamiltonian and convergence order over a long time interval. The results show the applicability of the methods considered.

(This is cited from the paper, which will be published in the journal, Mathematics and Computers in Simulation, 215 (2024) 420–439,IF=4.6,JCR:Q1)

8. Pre-classification based stochastic reduced-order model for time-dependent complex system

熊美馨 讲师 福建理工大学

摘 要： We propose a novel stochastic reduced-order model (SROM) for complex systems by combining clustering and classification strategies. Specifically, the distance and centroid of centroidal Voronoi tessellation (CVT) are redefined according to the optimality of proper orthogonal decomposition (POD), thereby obtaining a time-dependent generalized CVT, and each class can generate a set of cluster-based POD (CPOD) basis functions. To learn the classification mechanism of random input, the naive Bayes pre-classifier and clustering results are applied. Then for a new input, the set of CPOD basis functions associated with the predicted label is used to reduce the corresponding model. Rigorous error analysis is shown, and a discussion in stochastic Navier-Stokes equation is given to provide a context for the application of this model. Numerical experiments verify that the accuracy of our SROM is improved compared with the standard POD method.

9. Coupled LBM-DEM model for gas-liquid-solid interaction problems（线上）

费林林 研究员 瑞士苏黎世联邦理工学院

摘要： In this work, we propose a numerical model to simulate gas-liquid-solid interaction problems, coupling the lattice Boltzmann method and discrete element method (LBM-DEM). A cascaded LBM is used to simulate the liquid-gas flow field using a pseudopotential interaction model for describing the liquid-gas multiphase behaviour. A classical DEM resorting to fictitious overlaps between the particles is used to simulate the multiple-solid-particle system. A multiphase fluid-solid two-way coupling algorithm between LBM and DEM is constructed. The model is validated by four benchmarks: (i) single disc sedimentation, (ii) single floating particle on a liquid-gas interface, (iii) sinking of a horizontal cylinder and (iv) self-assembly of three particles on a liquid-gas interface. Our simulations agree well with the numerical results reported in the literature. Our proposed model is further applied to simulate droplet impact on deformable granular porous media at pore scale. The dynamic droplet spreading process, the deformation of the porous media (composed of up to thousands of solid particles), as well as the invasion of the liquid into the pores are well captured, within a wide range of impact Weber number. The droplet spreading dynamics on particles is analyzed based on the energy budget, which reveals mechanisms at play, showing the evolution of particle energy, surface energy and viscous dissipation energy. A scaling relation based on the impact Weber number is proposed to describe the maximum spreading ratio.

10. A high order operator splitting method for the nonlocal phase-field model

翟术英 副教授 华侨大学

摘要： We propose a second-order fast explicit operator splitting method for the phase model. The basic idea lied in our method is to split the original problem into linear and nonlinear parts. The linear subproblem is numerically solved using the Fourier spectral method, which is based on the exact solution and thus has no stability restriction on the time-step size. The nonlinear one is solved via second-order strong stability preserving Runge-Kutta method. The stability and convergence are discussed in L2-norm. Numerical experiments are performed to validate the accuracy and efficiency of the proposed method. Moreover, energy degradation and mass conservation are also verified.

11. A smoothing Newton method based on the modulus equation for a class of weakly nonlinear complementarity problem

黄宝华 副教授 福建师范大学

摘要： By equivalently transforming a class of weakly nonlinear complementarity problems into a modulus equation, and introducing a smoothing approximation of the absolute value function, a smoothing Newton method is established for solving the weakly nonlinear complementarity problem. Under some mild assumptions, the proposed method is shown to possess global convergence and locally quadratical convergence. Especially, the global convergence results do not need a priori existence of an accumulation point with some suitable conditions. Numerical results are given to show the efficiency of the proposed method.

12. A new view of a result on the doubly superstochastic matrices

黄少武 副教授 莆田学院

摘要： In this talk, we introduce Williamson's diagonal form for symmetric positive-semidefinite matrices, which provide a new way of viewing a result on the doubly superstochastic matrices.

13. 耦合自攀移的棱柱位错环攀移的相场模型

牛晓花 副教授 厦门理工学院

摘要： 我们提出了耦合自攀移的棱柱位错环攀移的相场模型。该模型结合了攀移力。在 Cahn-Hilliard /Allen-Cahn 框架下建立。渐近分析证明，所提出的相场模型严格地给出了尖锐界面极限下的位错攀移速度，该速度包含了空位管扩散驱动的自攀移运动。 最后，数值模拟验证了自攀移影响了棱柱形位错环演化的时间和形状，这对研究材料的性能有着重要意义。

14. Unconditionally stable and convergent difference scheme for superdiffusion with extrapolation（线上）

闫玉斌 教授 英国切斯特大学

摘要： Approximating the Hadamard finite-part integral by the quadratic interpolation polynomials, we obtain a scheme for approximating the Riemann-Liouville fractional derivative of order $\alpha \in (1,2)$ and the error is shown to have the asymptotic expansion $\left(d_3\tau^{3-\alpha}+d_4\tau^{4-\alpha}+d_5\tau^{5-\alpha}+\ldots\right)+\left(d_2^*\tau^4+d_3^*\tau^6+d_4^*\tau^8+\ldots\right)$ at any fixed time, where τ denotes the step size and $d_l, l=3,4,\ldots$ and $d_l^*, l=2,3,\ldots$ are some suitable constants. Applying the proposed scheme in temporal direction and the central difference scheme in spatial direction, a new finite difference method is developed for approximating the time fractional wave equation. The proposed method is unconditionally stable, convergent with order $O(\tau^{3-\alpha}), \alpha \in (1,2)$ and the error has the asymptotic expansion. Richardson extrapolation is applied to improve the accuracy of the numerical method. The convergence orders are $O(\tau^{4-\alpha})$ and $O(\tau^{2(3-\alpha)}), \alpha \in (1,2)$, respectively, after first two extrapolations. Numerical examples are presented to show that the numerical results are consistent with the theoretical findings.

15. Arbitrarily high order time-stepping method for the anisotropic phase-field dendritic crystal growth model

王未文 博士后 北京师范大学

摘要： In this paper, we develop and analyze a novel class of arbitrarily high-order and unconditionally energy stable schemes for the anisotropic phase-field dendritic crystal growth model, which is a highly nonlinear system that combines the anisotropic Allen-Cahn equation with the thermal equation. The proposed schemes are based on an extrapolated and linearized Runge-Kutta method for an auxiliary variable reformulation of the crystal growth model. A delicate implementation demonstrates that the proposed method can be realized in a very efficient way, requiring only the solution of a coupled linear elliptic system at each time step. We illustrate theoretically that the constructed schemes satisfy the energy dissipation property and give a consistency error analysis. Numerical experiments for two and three spatial dimensional problems are performed to verify our theoretical results as well as the efficiency of our proposed method. To the best of our knowledge, this is the first unconditional energy stable scheme of arbitrarily high order for the anisotropic phase-field dendritic crystal growth model.

16. Efficient iterative method for generalized Sylvester quaternion tensor equation

胡晶晶 博士研究生 福建师范大学

摘要： In this study, we employ the biconjugate residual (BCR) algorithm in tensor form to deal with the generalized Sylvester quaternion tensor equation in order to find the minimum norm solution. The proposed algorithm uses only tensor format. It can be proved that the proposed approach can find the solution with in a finite number of steps in the absence of round-off errors. Furthermore, we can get the unique minimal Frobenius norm solution by choosing special kinds of initial tensor. Finally, some numerical examples are reported to illustrate the feasibility of our algorithm, including the effectiveness of the algorithm in color video restoration problems.

17. Stabilized variational formulations of Chorin-type and artificial compressibility methods for the stochastic Stokes-Darcy equations

向亚红 博士研究生 厦门大学

摘要： We consider two different types of numerical schemes for the nonstationary stochastic Stokes-Darcy equations with multiplicative noise. Firstly, we consider the Chorin-type time-splitting scheme for the Stokes equation in the free fluid region. The Darcy equation and an elliptic equation for the intermediate velocity of free fluid coupled with the interface conditions are solved, and then the velocity and pressure in free fluid region are updated by an elliptic system. Secondly, we further consider the artificial compressibility method (ACM) which separates the fully coupled Stokes-Darcy model into two smaller subphysics problems. The ACM reduces the storage and the computational time at each time step, and allows parallel computing for the decoupled problems. The pressure in free fluid region only needs to be updated at each time step without solving an elliptic system. We utilize the RT_1-P_1 pair finite element space and the interior penalty discontinuous Galerkin (IPDG) scheme based on the BDM_1-P_0 finite element space in the spatial discretizations. Under usual assumptions for the multiplicative noise, we prove that both of the Chorin-type scheme and the ACM are unconditionally stable. Numerical examples are provided to verify the stability estimates for both of schemes. Moreover, we test the convergence rate for the velocity in time for both of schemes which is consistent with the implicit Euler scheme. The convergence rate for the pressure approximation in the time-averaged fashion is also tested.

18. 基于图神经网络的动作时序定位模型

陈乾泰 博士研究生 福州大学

摘要：随着信息技术的飞速发展，全球数据量呈现出爆炸式增长趋势，数据拥有者存储、管理和维护数据的成本不断增加。因图神经网络的结构的灵活性与可拓展性等优势，越来越多的产品将其应用在自己的开发中。动作时序定位是其中一项重要的应用领域，旨在在一个较长视频中确定其中的开始和结束时间,以及识别该动作类别。一个动作可以持续几帧甚至是十几秒，而在现实情况中短视频，也就是短于 30 秒的视频是占据主要地位的。因此，我们主要采用了图神经网络，来对短视频进行处理，从而提升了时序动作定位模型的精度和效果。

19. High order positivity-preserving nodal discontinuous Galerkin methods for anisotropic diffusion problems

刘鑫源 博士研究生 厦门大学

摘要： In this talk, we develop second and third order accurate positivity-preserving (PP) nodal discontinuous Galerkin (DG) methods for one and two dimensional anisotropic diffusion problems. The key idea is to first represent the cell average of its numerical approximation as a weighted summation of Gaussian quadrature point values used in the updating of nodal DG methods, and then transform these Gaussian quadrature point values to some other special chosen point values. We prove that by taking parameters in the definition of nodal DG methods appropriately, together with a suitable time stability condition, the cell averages can be kept positive. A polynomial scaling limiter is then applied to obtain positive numerical approximations on the whole cell without sacrificing accuracy. Stability analysis without the PP limiter is also rigorously established. Numerical experiments are performed to demonstrate desired orders of accuracy, PP and good performances of our propose approach.

20. An immersed boundary-lattice Boltzmann method for fluid-structure interactions involving viscoelastic fluids（线上）

田方宝 副教授 澳大利亚新南威尔士大学

摘要：本报告讲述作者研究团队从事非牛顿流动研究的起源、发展、以及从事非牛顿流固耦合研究的过程，并介绍针对涉及非牛顿流固耦合的内置边界-格子波尔兹曼方法。该方法采用格子玻尔兹曼方法求解流体动力学和非牛顿流体本构方程。为了增加数值稳定性，在非牛顿流体本构方程中引入人工粘性。固体动力学求解器包含针对二维胶囊、二维和三维的固体颗粒和弹性板的有限差分法，以及针对三维胶囊的有限元法。流固耦合是通过最简单的反馈力内置边界法来实现的。报告还将介绍大量的验证算例和若干物理问题的讨论。

21. High order conservative LDG-IMEX methods for the degenerate nonlinear non-equilibrium radiation diffusion problems

郑少钦 博士研究生 厦门大学

摘要： In this paper, we develop a class of high-order conservative methods for simulating non-equilibrium radiation diffusion problems. Numerically, this system poses significant challenges due to strong nonlinearity within the stiff source terms and the degeneracy of nonlinear diffusion terms. Explicit methods require impractically small time steps, while implicit methods, which offer stability, come with the challenge to guarantee the convergence of nonlinear iterative solvers. To overcome these challenges, we propose a predictor-corrector approach and design proper implicit-explicit time discretizations. In the predictor step, the system is reformulated into a nonconservative form and linear diffusion terms are introduced as a pernalization to mitigate strong nonlinearities. We then employ a Picard iteration to secure convergence in handling the nonlinear aspects. The corrector step guarantees the conservation of total energy, which is vital for accurately simulating the speeds of propagating sharp fronts in this system. For spatial approximations, we utilize local discontinuous Galerkin finite element methods, coupled with positive-preserving and TVB limiters. We validate the orders of accuracy, conservation properties, and suitability of using large time steps for our proposed methods, through numerical experiments conducted on one- and two-dimensional spatial problems. In both homogeneous and heterogeneous non-equilibrium radiation diffusion problems, we attain a time stability condition comparable to that of a fully implicit time discretization.

22. High order reduced basis for the Allen-Cahn equation

郭亚瑜 博士研究生 厦门大学

摘要： In this paper we carry out an error analysis for a reduced order method for the Allen-Cahn equation. We consider a time-space discretisation for which an error estimate of the full model solution is available. Specifically, the full discretisation is based on a stabilized auxiliary variable approach for the time stepping and a spectral Galerkin method for the spatial discretisation.The advantages of this full discretisation are its unconditional stability, the availability of error estimates and its ease of implementation. An estimate of the errors in the H^1 seminorm is rigorously derived for both the full order model and the reduced order model, which is then verified by some numerical examples.

23. Provably convergent Newton–Raphson methods for recovering primitive variables for relativistic hydrodynamics

蔡超仪 博士研究生 厦门大学

摘要： The relativistic hydrodynamics (RHD) equations consider relativistic effects on top of the compressible Euler equations, describing the motion of fluid when its velocity approaches the speed of light. When simulating the RHD equations, it is often necessary to compute the primitive variables, namely pressure, density and fluid velocity. However, the primitive variables of the RHD equations cannot be explicitly reformulated using conservative variables due to relativistic effects. To improve the efficiency and stability of the simulations for the RHD equations, we propose three efficient Newton–Raphson (NR) methods for robustly recovering primitive variables from conservative variables. Importantly, we rigorously prove that these NR methods are always convergent and physical-constraint-preserving (PCP), meaning they preserve the physical constraints (positivity of pressure and

density, and subluminal fluid velocity) throughout the NR iterations. The discovery of these robust NR methods and their PCP convergence analyses are highly nontrivial and technical. Our NR methods are versatile and can be seamlessly incorporated into any RHD schemes that require the recovery of primitive variables.

24. Stability and Error Analysis of SAV Schemes for Electrohydrodynamic Model with Variable Density

何育宇 博士研究生 厦门大学

摘要： We construct and analyze first- and second-order schemes based on scalar auxiliary variable (SAV) approach for the electrohydrodynamic (EHD) model with variable density. These schemes only require solving a sequence of linear differential equations plus a linear well-posed algebraic equation at each time step, and are unconditionally energy stable. We carry out a rigorous error analysis for the first-order semi-discrete SAV scheme in two-dimensional case and derive the maximum principle, the optimal error estimates and the regularity estimates. Numerical experiments verify the accuracy and stability of the presented schemes.

25. 云存储中基于区块链的数据完整性审计

许永亮 博士研究生 福州大学

摘要： 随着信息技术的飞速发展，全球数据量呈现出爆炸式增长趋势，数据拥有者存储、管理和维护数据的成本不断增加。因云存储其低成本、即时可用和按需付费等优势，越来越多的数据拥有者将他们的数据外包给云存储服务提供商，从而极大地减轻了数据管理负担。但数据拥有者将数据上传到云服务器后，会失去对数据的物理控制权，这使得云端数据的完整性成为了不可忽略的安全问题。数据完整性审计协议允许验证者利用同态聚合技术来验证远程数据的完整性，而无需下载外包数据。区块链的流行给数据完整性审计注入了新的活力，本次报告，我们将介绍我们最近基于区块链的数据完整性审计技术研究。

26. 多介质流问题的应用子单元限制器的间断 Galerkin 格式

吴峭 博士研究生 厦门大学

摘要： 多介质流是指流场涉及多种物质，且物质之间存在相互耦合作用的流体，其广泛存在于各种自然现象中，有着非常重要的科学研究意义和工程应用价值。多介质流中通常含有可变形界面，给此类问题的数值模拟带来了挑战。目前，文献中已有大量针对扩散界面模型的间断 Galerkin（discontinuous Galerkin，简称 DG）方法，这些方法将界面处理为多种介质相互扩散而成的混合区，取得了优秀的数值效果。然而，DG 方法的分辨率尚有提升空间。本报告将以体积分数模型为例，介绍多介质流问题的应用子单元限制器的 DG 格式。这是一个高阶、高分辨率且速度和压力无震荡的数值格式，它的基本特点是，在间断附近，将问题单元划分为子单元，并在其上使用有限体积法。该方法的优势在于，其在间断附近利用子单元均值代替单元上的多项式来逼近真解，有利于以更高的分辨率模拟间断。报告会介绍格式的实现细节，还会利用一维算例和二维算例证明格式精度阶达到最优且速度和压力无震荡，并证明子单元限制器在分辨率方面的优势。

27. On Krylov subspace methods for skew-symmetric and shifted skew-symmetric linear systems

王方 博士研究生 厦门大学

摘要： Krylov subspace methods for solving linear systems of equations involving skew-symmetric matrices have gained recent attention. In this work, we extend the results of Greif et al. to singular skew-symmetric linear systems. In addition, we systematically study three Krylov subspace methods (called S3CG, S3MR, and S3LQ) for solving shifted skew-symmetric linear systems. They all are based on Lanczos triangularization for skew-symmetric matrices, and correspond to CG, MINRES, and SYMMLQ for solving symmetric linear systems, respectively. To the best of our knowledge, this is the first work that studies S3LQ. We give some new theoretical results on S3CG, S3MR, and S3LQ. We also provide the relationship among the three methods and those based on Golub--Kahan bidiagonalization and Saunders--Simon--Yip tridiagonalization. Numerical examples are given to illustrate our theoretical findings.

28. Kirchhoff-Love shell representation and analysis using triangle configuration B-splines

王志好 博士研究生 厦门大学

摘要： This paper presents the application of triangle configuration B-splines (TCB-splines) for representing and analyzing the Kirchhoff-Love shell in the context of isogeometric analysis (IGA). TCB-splines offer flexibility in modeling complex geometries with C^1 continuity, making them naturally fit into the Kirchhoff-Love shell formulation with complex geometries. We first propose a linear least-squares-based framework to reparametrize the mid-surface of a thin shell, which consists of multiple (trimmed) NURBS patches and is topologically equivalent to an open disk with a finite number of holes, into a single TCB-surface defined over a carefully computed parametric domain. We then utilize TCB-splines for geometric representation and solution approximation in shell analysis. We verify the accuracy and robustness of our method by applying it to linear and nonlinear benchmark shell problems. The applicability of the proposed approach to shell analysis is further exemplified by performing geometrically nonlinear Kirchhoff-Love shell simulations of a pipe junction and a front bumper represented by a single patch of TCB-splines.

29. Prediction-correction threshold dynamics method for topology optimization of steady-state heat transfer problems

董飘飘 博士研究生 厦门大学

摘要： In this paper, we propose a prediction-correction threshold dynamics method for solving the topological optimization problem of steady-state heat transfer equations. The problem is formulated as a minimization problem incorporating the complementary energy, with the perimeter approximated using nonlocal energy and is subject to steady-state heat transfer conditions. The material regions are represented using an indicator function. The indicator function is updated by performing simple convolutions followed by thresholding. The numerical results clearly illustrate the superior effectiveness of our proposed method when compared to the threshold dynamics approach. Moreover, the various numerical results demonstrate that our proposed algorithm guarantees the property of energy decrease in the 2D domain.

30. Global optimization of optimal Delaunay triangulation with modified whale optimization algorithm

翁咏佳 博士研究生 厦门大学

摘要： In this paper, we introduce an innovative approach to generate a high- quality mesh with a density function in a given domain. Our method involves solving a variational problem that optimizes the energy func- tion of the optimal Delaunay triangulation (ODT). To achieve this, we have developed a modified whale optimization algorithm (MWOA) based population that is combined with the quasi-Newton method (L- BFGS) to optimize ODT energy on a global level. Our experiments have demonstrated the impressive efficiency of this optimization algorithm in searching for better minima and producing high-quality meshes. Remark- ably, the algorithm's powerful global optimization capability makes it insensitive to initialization, which eliminates the need for any special initialization procedures. Furthermore, our proposed algorithm can easily handle complex domains and non-uniform density functions, making it a versatile tool for mesh generation. Overall, our method offers a promising solution for generating practicable meshes with a density function.

31. An increasing rank Riemannian method for generalized Lyapunov equations

黄振威 博士研究生 厦门大学

摘要： In this paper, we consider finding a low-rank approximation to the solution of a large-scale generalized Lyapunov matrix equation in the form of $AXM+MXA=C$, where A and M are symmetric positive definite matrices. An algorithm called an Increasing Rank Riemannian method for generalized Lyapunov equation (IRRLyap) is proposed by merging the increasing rank technique and Riemannian optimization techniques on the quotient manifold $\mathbb{R}_*^{n\times p}/\mathcal{O}_p$. To efficiently solve the optimization problem on $\mathbb{R}_*^{n\times p}/\mathcal{O}_p$, a line-search-based Riemannian inexact Newton method is developed with its global convergence and local superlinear convergence rate guaranteed. Moreover, we investigate the influence of the existing three Riemannian metrics on $\mathbb{R}_*^{n\times p}/\mathcal{O}_p$ and derive new preconditioners which takes $M \neq I$ into consideration. Numerical experiments show that IRRLyap with one of the Riemannian metrics is most efficient and robust in general and is preferable compared to the tested state-of-the-art methods when the lowest rank solution is desired.

32. Neural Operator Learning Enhanced Physics-informed Neural Networks for solving differential equations with sharp solutions

林斌 硕士研究生 厦门大学

摘要： In this talk, we will introduce an operator learning enhanced PINN (OL-PINN) to solve this kind of singular problems (jointed with Zhiping Mao). The present method can sufficiently decrease the error between the prediction and exact solution than the vanilla PINN and extrapolation of DeepONet. What's more, our methods show another potential advantage that it can possesse the ability of solving problem with insufficient initial-boundary conditions. Further, we use several numerical examples to demonstrate the effectiveness of the present method.