数字机理模型计算与反演国际研讨会

International Workshop on Computation and Inversion of Digital Mechanism Model

上海财经大学 数学学院 计算科学与金融数据研究中心

2024 年 12 月 13 日-15 日

International Workshop on Computation and Inversion of Digital Mechanism Model

数字机理模型计算与反演国际研讨会

为增强上海财经大学数学学院数字化机理建模与应用研究团队与境内外学者的学术交流与合作，探讨现代应用数学特别是数字机理模型计算与反演方面的研究新进展，上海财经大学数学学院将于2024年12月13-15日举办“International Workshop on Computation and Inversion of Digital Mechanism Model（数字机理模型计算与反演国际研讨会）”，会议将邀请境内外计算数学及反问题领域专家和青年学者进行线上、线下混合形式的学术研讨与交流。

会议主办：上海财经大学数学学院，计算科学与金融数据研究中心

会议组织：上海财经大学数学学院数字化机理建模与应用研究团队

江渝，许伯熹，严阅，陈瑜，张晔宇，刘欢

会议时间：2024 年 12 月 13 日 - 12 月 15 日

会议地点：上海财经大学红瓦楼 826 室

在线会议链接：

https://meeting.tencent.com/dm/LLE3xgdpFdyb

腾讯会议：427-235-907　会议密码：6666

会议日程：

时间	报告人	内容	主持人
12 月 13 日下午	地点：红瓦楼 826 室		
14：30-17：00	圆桌讨论		
12 月 14 日上午	地点：红瓦楼 826 室		
9：00-9：10	开幕式		江渝
9：15-9：40	Wang Cheng（线上）	Global in time numerical stability for nonlinear PDEs	Huang Huaxiong
9：40-10：05	牟长虹（线上）	Combining Stochastic Parameterized Reduced-Order Models With Machine Learning for Data Assimilation and Uncertainty Quantification With Partial Observations	
10：05-10：30	王宇青（线上）	Natural Neural Networks Modeling and AI Application in Finance	
10：30-10：45	中间休息		
10：45-11：10	王海兵	Locating point sources in a diffusive medium by a non-iterative method	江渝
11：10-11：35	李文彬（线上）	Attempts in developing learning methods for inverse problems in imaging	
12 月 14 日下午	地点：红瓦楼 826 室		
13：30-13：55	王薇	Landweber iteration for inverse problems using multiple repeated measurements data in Banach spaces	许伯熹
13：55-14：20	钟敏(线上)	Dynamic Levenberg-Marquardt algorithm with uniformly convex constraints based on sequential data	
14：20-14：45	李婷月	Quantitative Runge approximation for Lamé system and its applications to numerical methods	
14：45-15：00	中间休息		
15：00-15：25	张晔宇	海洋大气数据同化相关	严阅
15：25-15：50	刘欢	分数阶微分方程数值解相关	
15：50-16：15	韦雨骁	焦散型介质中高频波动方程的渐近方法	
12 月 15 日上午	地点：红瓦楼 826 室		
10：00-12：00	研讨与总结		

摘要

Global in time numerical stability for nonlinear PDEs

Wang Cheng

University of Massachusetts Dartmouth

Uniform in time numerical stability for certain nonlinear PDEs, such as incompressible fluid flow and a few bi-stable gradient flow models, are presented in this talk. For 2-D incompressible Navier-Stokes equation, a global bound in L^2 and H^m norms for the numerical solution is obtained. For the bi-stable gradient flows, such as the epitaxial thin film growth with slope selection, the convexity splitting nature of the numerical scheme assures its non-increasing energy. Some long time numerical simulations will also be presented.

Combining Stochastic Parameterized Reduced-Order Models With Machine Learning for Data Assimilation and Uncertainty Quantification With Partial Observations

牟长虹

Purdue University

A hybrid data assimilation algorithm is developed for complex dynamical systems with partial observations. The method starts with applying a spectral decomposition to the entire spatiotemporal fields, followed by creating a machine learning model that builds a nonlinear map between the coefficients of observed and unobserved state variables for each spectral mode. A cheap low-order nonlinear stochastic parameterized extended Kalman filter (SPEKF) model is employed as the forecast model in the ensemble Kalman filter to deal with each mode associated with the observed variables. The resulting ensemble members are then fed into the machine learning model to create an ensemble of the corresponding unobserved variables. In addition to the ensemble spread, the training residual in the machine learning-induced nonlinear map is further incorporated into the state estimation, advancing the diagnostic quantification of the posterior uncertainty. The hybrid data assimilation algorithm is applied to a precipitating quasi-geostrophic (PQG) model, which includes the effects of water vapor, clouds, and rainfall beyond the classical two-level QG model. The complicated nonlinearities in the PQG equations prevent traditional methods from building simple and accurate reduced-order forecast models. In contrast, the SPEKF forecast model is skillful in recovering the intermittent observed states, and the machine learning model effectively estimates the chaotic unobserved signals. Utilizing the calibrated SPEKF and machine learning models under a moderate cloud fraction, the resulting hybrid data assimilation remains reasonably accurate when applied to other geophysical scenarios with nearly clear skies or relatively heavy rainfall, implying the robustness of the algorithm for extrapolation.

Natural Neural Networks Modeling and AI Application in Finance

王宇青

Kmeit Global Inc. Hong Kong, PRC
&
Cynorisk Analytics Inc., Canada

The presentation reviews the natural neural network modeling effort in physics, especially pioneered by J.J. Hopfield who won 2024 Nobel Prize in Physics. The application of neural network in finance is also discussed.

Locating point sources in a diffusive medium by a non-iterative method

王海兵

东南大学

We consider the localization of the point sources in a diffusive medium from a single boundary measurement, which can be formulated as an inverse source problem for a diffusion equation. First, using the unique continuation property of solutions to the diffusion equation, we establish the uniqueness of this inverse problem. Then, we develop a non-iterative method called the range test (RT) to recover the locations of the point sources. That is, for the point sources located inside a bounded domain Ω, we can detect their locations by examining the solvability of a specified boundary integral equation for a given test domain G. Next, we design a numerical algorithm to locate a single point source from the boundary measurement. Moreover, to further show the effectiveness of the RT, we provide two algorithms for two specific cases of multiple point sources: one is that there are two point sources in Ω, and the other is that all point sources are distributed inside a certain annular domain. The algorithms enable us to locate the point sources and estimate the relative magnitude of their intensities in the second case. Then, we carry out various numerical experiments to demonstrate the efficiency and effectiveness of our algorithms. Furthermore, for the case that a single point source moves inside Ω, we also give a numerical scheme to track its trajectory.

Attempts in developing learning methods for inverse problems in imaging

李文彬

哈尔滨工业大学（深圳）

We will briefly report out attempts in developing learning methods for inverse problems in imaging. (1) Learning on the correctness class: end-to-end learning approaches are efficient but lack of reliability; learning on the correctness class is helpful to alleviate this problem, and we will discuss it in the domain inverse problems of gravimetry. (2) Two-step neural networks with iterative algorithms: including model-based iterative algorithms into the construction of neural networks, it is helpful to improve the generalization ability of the learning methods. (3) Data-driven regularization: build a data-driven regularizer for the inversion algorithm through neural networks and learning techniques, where we will briefly mention the iNETT method and the graphLaNet algorithm.

Landweber iteration for inverse problems using multiple repeated measurements data in Banach spaces

王薇

嘉兴大学

In this work, we consider Landweber iteration for solving generic linear inverse problems in the Banach spaces setting. Landweber iteration, along with its variants, is widely recognized as one of the most prominent iterative regularization methods due to its ease of implementation. Unlike classical theoretical analyses, this work considers the absence of noise level information, making it more relevant to real-world applications. We assume that multiple repeated independent identically distributed unbiased measurements of the exact data are available. The average of these repeated measurements is then utilized to update the iterative process. Under a statistical variant of the discrepancy principle, we establish rigorous regularizing property in the sense of expectation. Furthermore, a series of numerical experiments are conducted to evaluate and validate the performance of the approach.

Dynamic Levenberg-Marquardt algorithm with uniformly convex constraints based on sequential data

钟敏

东南大学

Extracting the useful information and assimilating the new data are very important in many parameter identification problems and state estimation problems, the full utilization of newly generated data can produce fast reconstructions. In this manuscript, a data-driven statistical nonlinear regularization method called IRLM-Θ is proposed in the presence of sequential data and random noise. The algorithm is specifically based on the classical Levenberg-Marquardt method, where the uniformly convex functional Θ is chosen according to the regularity information of the sought solution. Different types of observations are considered, which leads to offline averaged IRLM-Θ and online dynamical IRLM-Θ algorithms respectively. Two parameter identification problems are finally presented to illustrate the efficiency and feasibility of our proposed method.

Quantitative Runge approximation for Lamé system and its applications to numerical methods

李婷月

复旦大学

The quantitative Runge approximation is significant for inverse problems and learning-based numerical methods. In this talk, we firstly give both qualitative and quantitative Runge approximation properties for the Lamé system, considering the optimal regular conditions of the Lamé coefficients. They rely on quantitative unique continuation results and duality arguments. Compared with the qualitative Runge approximation, the quantitative Runge approximation requires a rather strong condition, the integral ellipticity condition, for Lamé coefficients to ensure Lp-Integrability of the solution's gradient. Based on the Helmholtz decomposition, we propose a learning based numerical method for the Lamé system. The quantitative Runge approximation yields the Hölder-type and logarithm-type error estimates for numerical methods, correspondingly.

焦散型介质中高频波动方程的渐近方法

韦雨骁

香港科技大学

Numerical simulation of high-frequency wave fields is critical in fields such as electromagnetics and geophysics. In this work, we develop novel Hadamard integrators for self-adjoint wave equations in both time and frequency domain in an inhomogeneous medium. Based on asymptotic ansatz of Green's function and butterfly algorithms, the proposed methods can construct high-frequency wave field beyond caustics implicitly and advance spatially overturning waves in time naturally with quasi-optimal computational complexity and memory usage. Numerical examples illustrate the accuracy and efficiency of the proposed methods.