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Book of Program

6.28-7.1, 2024

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Organized by

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EASIAM 2024, 29 June – 1 July 2024, Macau

Schedule

	Day 1(June 29)	Day 2(June 30)	Day 3(July 1)
8:30 - 8:50	Opening & Photos		Invited Talk
8:50 - 9:00		Plenary Talk	**Shizuo Kaji**
9:00 - 9:10		**Zuowei Shen**	
9:10 - 9:30	Plenary Talk		Invited Talk
9:30 - 9:50	**Hans De Sterck**	Coffee Break	**Yueh-Cheng Kuo**
9:50 - 10:00			
10:00 - 10:10			Coffee Break
10:10 - 10:20	Coffee Break		
10:20 - 10:30			
10:30 - 11:00	Invited Talk		
11:00 - 11:10	**Jingrun Chen**	Parallel Session II	
11:10 - 11:30	Invited Talk		Parallel Session IV
11:30 - 11:50	**Yuwei Fan**		
11:50 - 12:00			
12:00 - 12:20			
12:20 - 12:30	Lunch Break	Lunch Break	
12:30 - 14:00			
14:00 - 14:20		Invited Talk	
14:20 - 14:40		**Akiko Fukuda**	
14:40 - 15:00	SPP Session	Invited Talk	
15:00 - 15:20	Coffee Break	**Wei Gong**	
15:20 - 15:30		Coffee Break	
15:30 - 15:50			
15:50 - 16:00			
16:00 - 16:30			
16:30 - 17:00	Parallel Session I		
17:00 - 17:30		Parallel Session III	
17:30 - 18:00			
18:00 - 18:30			
18:30 - 20:30		Banquet	

Remark: All plenary talks, invited talks and SPP session will be held in E4-G078.

Plenary and Invited Talk

Room: E4-G078 Plenary Talk		
(June 29th)9:00-10:00	Hans De Sterck[1]	Multigrid parallel-in-time methods for nonlinear hyperbolic PDE systems
(June 30th)8:30-9:30	Zuowei Shen[2]	Deep Approximation via Deep Learning
Room: E4-G078 Invited Talk		
(June 29th)10:30-11:10	Jingrun Chen[3]	AI-enabled Differentiable Methods for Computer-aided Design and Engineering
(June 29th)11:10-11:50	Yuwei Fan[4]	Some Computational Mathematics Challenges in HUAWEI Engineering Applications
(June 30th)14:00-14:40	Akiko Fukuda[5]	Ultradiscrete integrable systems and eigenvalue algorithms over min-plus algebra
(June 30th)14:40-15:20	Wei Gong[6]	PDE-constrained shape optimization: shape gradients, convergence and well-posedness
(July 1st)8:30-9:10	Shizuo Kaji[7]	Designing a Kinematic Chain through Point Configuration on the Two Sphere
(July 1st)9:10-9:50	Yueh-Cheng Kuo[8]	Structure-Preserving Doubling Algorithms for Nonlinear Matrix Equations

Mini-Symposium List
MS-M01 Recent Advances in Uncertainty Quantification, Scientific Computing and Data Science Organizers: Zhiwen Zhang, University of Hong Kong Liu Liu, Chinese University of Hong Kong
MS-M02 Numerical methods for geometric PDEs and their applications in fluids and solids Organizers: Weizhu Bao, National University of Singapore Yifei Li, National University of Singapore
MS-M03 Recent Advances in Orthogonalization Organizers: Meiyue Shao, Fudan University
MS-M04 Recent Advances in Applications and Numerical Techniques for Partial Differential Equations Organizers: Sean Hon, Hong Kong Baptist University Shingyu Leung, Hong Kong University of Science and Technology
MS-M05 Matrix Computation and Its Applications Organizers: Peter Chang-Yi Weng, National Chiayi University
MS-M06 Modeling and Simulation for Materials Science and Deep Learning Organizers: Yuqing Li, Shanghai Jiao Tong University Zecheng Gan, The Hong Kong University of Science and Technology (Guangzhou)
MS-M07 Non-linear PDEs and their New Challenges Organizers: Hisashi Okamoto, Gakushuin University
MS-M08 SIAM Student Chapter Research Presentations I Organizers: Chuqi CHEN, Hong Kong University of Science and Technology Chushan WANG, National University of Singapore Zishang Li, The Chinese University of Hong Kong
MS-M09 SIAM Student Chapter Research Presentations II Organizers: Kota Takeda, Kyoto University Yingzhi Du, City University of Hong Kong Kazuya Okamoto, Waseda University Zishang LI, Chinese University of Hong Kong
MS-M10 Recent progress in modeling and computational methods for interface problems Organizers: Chaozhen Wei, University of Electronic Science and Technology of China Zhen Zhang, Southern University of Science and Technology
MS-M11 Several aspects of pattern formation in nonlinear differential equations Organizers: Takiko Sasaki, Musashino University Tetsuji Tokihiro, Musashino University
MS-M12 Interplay of stochastic dynamics and machine learning Organizers: Xiang ZHOU, City University of Hong Kong Lihu XU, University of Macau
MS-M13 Applied Mathematics and Machine Learning: Innovations Across Disciplines Organizers: Gangnan Yuan, Great Bay University
MS-M14 Scientific Computing Software and Its Applications Organizers: Zeyu Jin, Peking University Yixiao Lu, Peking University Min Zhang, Peking University
MS-M15 Recent Advances in Numerical Shape Optimization Methods: From Theory to Practice Organizers: Wei GONG, Chinese Academy of Sciences Shengfeng ZHU, East China Normal University Julius Fergy RABAGO, Kanazawa University

Parallel Session I

June 29, 2024

Room: E22-1008, June 29 MS-M04		
15:30 - 16:00	Myungjoo Kang[9]	Surface Reconstruction from Point Clouds
16:00 - 16:30	Siu-Long Lei[10]	Multilevel circulant preconditioner for high-dimensional fractional Laplacian
16:30 - 17:00	Kei Fong Lam[11]	Numerical analysis and simulation of a model for Stereolithography in 3D printing
17:00 - 17:30	Davide Bianchi[12]	A data-dependent regularization method based on the graph Laplacian
Room: E22-1009, June 29 MS-M05		
16:30 - 16:00	Matthew M. Lin[13]	Revealing Entanglement through Low-Rank Approximation
16:00 - 16:30	Ching-Sung Liu[14]	Fast Newton-Noda iteration for computing the ground states of nonlinear Schrodinger equations
16:30 - 17:00	Chun-Yueh Chiang[15]	Some equilibrium Hermitian so- lutions of the conjugate discrete- time algebraic Riccati equation
17:00 - 17:30	Hung-Yuan Fan[16]	An accelerated technique for computing extremal solutions of discrete-time algebraic Riccati equations

Room: E4-G068, June 29 Type Student I		
15:30 - 16:00	Chuqi Chen[17]	Exploring the Advantages of Random Feature Method in Solving PDEs: Insights from the Perspective of Optimization Difficulty
16:00 - 16:30	Qiguang Chen[18]	A learning framework for map- ping problems via Quasiconformal geometry
16:30 - 17:00	Chenran LIN[19]	Harmonic Beltrami Signature and Shape Prior Segmentation
17:00 - 17:30	Zhipeng Zhu[20]	Parallel Computation of Quasi- conformal Mappings via Conformal Welding
Room: E22-1016, June 29 MS-M10		
15:30 - 16:00	Yang Xiang[21]	Deep Operator-Splitting Net- work for Solving PDEs
16:00 - 16:30	Shuyang Dai[22]	Contact Boundary Condition for Dislocation Dynamics Simulation in Crystal
16:30 - 17:00	Hao Wang[23]	Force-based blended atomistic to higher-order continuum coupling method
17:00 - 17:30	Xinpeng Xu[24]	Simulation Method of Microscale Fluid-Structure Interactions: Diffuse-Resistance-Domain Approach
Room: E22-2010, June 29 MS-M14		
15:30 - 15:55	Hehu Xie[25]	Numerical Methods for Eigenvalue Problems
15:55 - 16:20	Kailiang Wu[26]	DUE: Deep Learning for Model- ing Unknown Equations
16:20 - 16:45	Dao XIANG[27]	Development and Reflection on Domestic Scientific Computing and System Simulation Software
16:45 - 17:10	Yang Kuang[28]	Multi-mesh adaptive finite element methods in electronic structure calculations
17:10 - 17:35	Zhichao Peng[29]	A Reduced Order Model Enhanced Iterative Solver for Parametric Radiative Transfer Equation
Room: E22-2011, June 29 MS-M15		
15:30 - 16:00	Jiajie Li[30]	Unconditionally energy stable gradient flow schemes for shape optimization in Navier-Stokes flow
16:00 - 16:30	Ziyi Zhang[31]	A novel shape optimization approach for the source identification of elliptic equations
16:30 - 17:00	Julius Fergy Rabago[32]	A non-conventional shape optimization method for shape identification problems
17:00 - 17:30	Jingfeng Wang[33]	A mechanism-driven reinforcement learning framework for shape optimization of airfoils

Room: E22-2014, June 29 Contributed Talk		
15:30 - 16:00	Yunjue Gu[34]	Fast Elasticity Parameters Estimating with Iterative Choice of Regularization Parameter and Continuation Method
16:00 - 16:30	QiangZhang[35]	Quantitative Theory for Richtmyer-Meshkov Instability in Compressible Fluids
16:30 - 17:00	Shuai Su[36]	Positivity-preserving finite volume schemes for radiation diffusion equations on general meshes
17:00 - 17:30	Fei Xu[37]	Acceleration of self-consistent field iteration for electronic structure calculations
Room: E22-2015, June 29 Contributed Talk		
15:30 - 16:00	Angelyn Lao[38]	Maintaining the Productivity of Co-culture Systems in the Face of Environmental Change
16:00 - 16:30	Yangjia Bao[39]	Analysis of the 9th Chebyshev Method in Non-Convex Non-Smooth Optimization Problems
16:30 - 17:00	Junyan Chu[40]	Vector Field Reconstruction on Convex Polygonal Domains based on Hyperplane Arrangement
17:00 - 17:30	Feifei Jing[41]	On Finite Volume Methods for a Class of Variational Inequalities Arising in Hydrodynamics
Room: E22-2017, June 29 Contributed Talk		
15:30 - 16:00	Yogi Erlangga[42]	Parallel-in-Time Multilevel Krylov Method
16:00 - 16:30	Rong Yang[43]	Self-generated magnetic field coupling Radiation-hydrodynamic numerical simulations In ICF
16:30 - 17:00	Shuanggui Li[44]	Radiation-hydrodynamics with a high-order, low-order method applied in ICF implosion simulation
17:00 - 17:30	Guanyu Zhou[45]	Numerical method for the crack problem with a Signorini-type contact condition on a linear combination of displacement and velocity
Room: E22-1002, June 29 Contributed Talk		
15:30 - 16:00	Shu Wang[46]	The Initial Value Problem for the Equations of Motion of Fractional Compressible Viscous Fluid
16:00 - 16:30	Xue Jiang[47]	A PML method for signal-propagation problems in axon
16:30 - 17:00	Yuntong Huang[48]	A numerical study for deformation-induced amorphization
17:00 - 17:30	Tsung-Ming Huang[49]	A nnU-Net-Based Brain Tumor Segmentation via Optimal Mass Transportation Pre-processing
Room: E4-G062, June 29 MS-M12		
15:30 - 15:55	Jinqiao Duan[50]	Data-Driven Stochastic Dynamics - Extracting Governing Laws amp Detecting Critical Transitions
15:55 - 16:20	Zuoqiang Shi[51]	Reconstruction of dynamical systems without time label
16:20 - 16:45	Jing Wu[52]	On one-dimensional Mckean-Vlasov stochastic variational inequalities
16:45 - 17:10	Jiayu Zhai[53]	Nonlinear Expectation Inference for the Uncertainty Quantification equation
17:10 - 17:35	Yu Cao[54]	Exploring the Optimal Choice for Generative Processes in Diffusion Models
17:35 - 18:00	Zhiqiang Cai[55]	Weak Generative Sampler to Efficiently Sample Invariant Distribution of Stochastic Differential Equation

Parallel Session II

Morning, June 30, 2024

Room: E22-1002, June 30 MS-M02		
10:00 - 10:30	Tiezheng Qian[56]	Onsager's Variational Principle: Theory and Applications
10:30 - 11:00	Xianmin XU[57]	Applications of the Onsager principle in numerical analysis
11:00 - 11:30	Zhen Zhang[58]	Sharp interface limit and numerical methods for a ternary phase-field model
11:30 - 12:00	Chunmei Su[59]	Parametric finite element methods for geometric flows
Room: E22-1008, June 30 MS-M04		
10:00 - 10:30	Wenbin Li[60]	Data and knowledge driven approaches for inverse problems in imaging
10:30 - 11:00	Kwunlun Chu[61]	A Constrained Least-Squares Ghost Sample Points (CLS-GSP) Method for Differential Operators on Point Clouds
11:00 - 11:30	Grigorios Tachyridis[62]	Band-times-Circulant preconditioners for non-symmetric Toeplitz systems
Room: E22-1009, June 30 MS-M05		
10:00 - 10:30	Peter Chang-Yi Weng[63]	A refinement of approximate in- variant subspaces of matrices based on SVD in high dimensionality reduction and image compression
10:30 - 11:00	Yung-Ta Li[64]	Recent advances of integration preconditioning techniques of pseudo spectral methods
11:00 - 11:30	Li-Gang Lin[65]	Exact Optimization: Application Spectrum

Room: E22-1011, June 30 MS-M06		
10:00 - 10:30	Kai Jiang[66]	Recent progress on numerical methods for quasiperiodic systems
10:30 - 11:00	Shuyang Dai[67]	Optimization approach for dislocation structures and evolution
11:00 - 11:30	Luchan Zhang[68]	Continuum Models for the Structure and Dynamics of Hetero- interfaces in Crystalline Materials
11:30 - 12:00	Zhiguo Yang[69]	Unconditionally SO(3)-preserving and energy-stable rotational discrete gradient schemes for orthonormal frame gradient flow
Room: E4-G053, June 30 Type Student II		
10:00 - 10:25	Kota Takeda[70]	Mathematical Analysis of the Ensemble Kalman filter
10:25 - 10:50	Harumi Shuei[71]	Optimizing Strategy of Player Matching Queue of Online Games
10:50 - 11:15	Kangming Chen[72]	Riemannian conditional gradient methods for composite optimization problems
11:15 - 11:40	Huimin Li[73]	A Strong Second-Order Optimality Condition for Nonlinear Semidefinite Optimization
11:40 - 12:05	Takatora Suzuki[74]	Combinatorics of Phylogenetic Networks: Understanding Deviations from Tree-Based Networks
Room: E4-G062, June 30 MS-M12		
10:00 - 10:20	Nan Chen[75]	A Two Timescale Evolutionary Game Approach to Multi-Agent Learning and its Application in Algorithmic Collusion Study
10:20 - 10:40	Yi Zhu[76]	TD learning for high- dimensional PIDEs with jumps
10:40 - 11:00	Shixiao Jiang[77]	Generalized Moving Least-Squares Methods for Solving Scalar- and Vector-Valued PDEs on Manifolds
11:00 - 11:20	Kejun Tang[78]	Deep adaptive sampling for surrogate modeling without labeled data
11:20 - 11:40	Chen Cui[79]	A neural multigrid solver for Helmholtz equations with high wavenumber and heterogeneous media
11:40 - 12:00	Yahong Yang[80]	Deeper or Wider: A Perspective from Optimal Generalization Error with Sobolev Loss
Room: E22-2010, June 30 MS-M14		
10:00 - 10:25	Ruchi Guo[81]	Optimization and preconditioning: TPD algorithms for nonlinear PDEs
10:25 - 10:50	Geshuo Wang[82]	Real-time simulation of open spin models with tensor operations
10:50 - 11:15	Guosheng Yin[83]	R Package CFO: Calibration-Free Odds Designs for Dose-Finding Clinical Trials
11:15 - 11:40	Zhengyu Huang[84]	Mars landing parachute simulation with AERO-Suite
11:40 - 12:05	Hongfei Zhan[85]	TSEMLib: a tetrahedral spectral element method based C++ library for high-order numerical solutions of PDEs

Room: E22-2014, June 30 Contributed Talk		
10:00 - 10:30	Mei-Heng Yueh[86]	Optimal Mass Transport Mappings with Application to Brain Tumor Segmentation
10:30 - 11:00	Dharma Lesmono[87]	Optimal replenishment policy for a deteriorated inventory model with time and stock-dependent demand
11:00 - 11:30	Ping Zeng[88]	Analysis of an energy-dissipating finite volume scheme on admissible mesh for the aggregation-diffusion equations
Room: E22-2015, June 30 Contributed Talk		
10:00 - 10:30	Jingyan Hu[89]	The well-posedness and discontinuous Galerkin approximation for the Non-Newtonian Stokes-Darcy-Forchheimer coupling system
10:30 - 11:00	Chien-Chang Yen[90]	Direct self-gravitational force calculation of infinitesimally thin gaseous disks based on adaptive mesh refinement accelerated by the fast Fourier transform
11:00 - 11:30	Darlington S. David[91]	Dynamics of Heteroclinic Networks: Unraveling Complex Interactions and Stability
Room: E22-2017, June 30 Contributed Talk		
10:00 - 10:30	Qi Wang[92]	The mixed method with two Lagrange multiplier formulations for the Signorini problem
10:30 - 11:00	Sungha Yoon[93]	Splitting-based numerical algorithm for reaction-diffusion systems
11:00 - 11:30	Fatimah Abdul Razak[94]	Unveiling Community Structures in Networks: with Insights from China's Migration Patterns

Parallel Session III

Afternoon, June 30, 2024

Room: E22-1002, June 30 MS-M02		
16:00 - 16:30	Weizhu Bao[95]	A structure-preserving parametric finite element method for geometric PDEs and applications
16:30 - 17:00	Buyang Li[96]	New artificial tangential motions for parametric finite element approximation of surface evolution
17:00 - 17:30	Yifei Li[97]	A structure-preserving parametric finite element method for geometric flows with anisotropic surface energy
17:30 - 18:00	Quan Zhao[98]	A variational front-tracking method for multiphase flow
Room: E22-1008, June 30 MS-M04		
16:00-16:30	Yuanyuan Huang[99]	A novel fourth-order scheme for two-dimensional Riesz space fractional nonlinear reaction- diffusion equations and its optimal preconditioned solver
16:30 - 17:00	Yedan Shen[100]	A convergence analysis based on the multi-mesh adaptive finite element method for Kohn-Sham models in all-electron calculations
17:00 - 17:30	Dingtao Shen[101]	NURBS-Enhanced Finite Element Method for the Phonon Boltzmann Transport Equation
17:30 - 18:00	Hao Liu[102]	Robust PDE Identification from a Noisy Data Set
Room: E22-1011, June 30 MS-M06		
16:00 - 16:30	Xiaofei Zhao[103]	Normalized DNN for ground states of BEC
16:30 - 17:00	Tao Luo[104]	Structure and Gradient Flow Near Global Minima of Two-layer Neural Networks
17:00 - 17:30	Yuqing Li[105]	Universality of Condensation in Neural Networks Trained by Various Algorithms
17:30 - 18:00	Zheng-An Chen[106]	Dynamics of initial condensation in neural networks
Room: E4-G053, June 30 Type Student II		
15:50 - 16:15	Yingzhi Du[107]	Uniform Regularity for Incompressible MHD Equations in a Bounded Domain with Curved Boundary in 3D
16:15 - 16:40	Jianfei Li[108]	SignReLU neural network and its approximation ability
16:40 - 17:05	kazuya Okamoto[109]	Double hump in a 5-neighbor cel- lular automaton
17:05 - 17:30	Zhiwen Zhang[110]	Landau damping for the high dimensional two-species Vlasov- Poisson system
17:30 - 17:55	Zishang Li[111]	An iterative constraint energy minimizing generalized multi-scale finite element method for contact problem

Room: E4-G068, June 30 Type Student I		
16:00 - 16:30	Yixuan ZHANG[112]	Algorithms for Topology Optimization Based on Bi-level Models and Variational Inequalities
16:30 - 17:00	Chushan Wang[113]	Error estimates of numerical methods for the nonlinear Schrquotodinger equation with low regularity potential and nonlinearity
17:00 - 17:30	Cunxin Huang[114]	Non-convergence Analysis of Probabilistic Direct Search
17:30 - 18:00	Chutian Huang[115]	PF-ABGen: A Reliable and Ef- ficient Antibody Generator via Poisson Flow

Room: E22-1016, June 30 MS-M10		
16:00 - 16:30	Wei Jiang[116]	High order in time, BGN-based parametric finite element meth- ods for solving geometric flows
16:30 - 17:00	Lu Nan[117]	Decoupled and energy stable schemes for a phase-field surfactant model based on a operator splitting technique
17:00 - 17:30	Xurong Chi[118]	The Random Feature Method for Solving Interface Problems
17:30 - 18:00	Xueping Zhao[119]	Wetting dynamics with surface binding
Room: E4-G062, June 30 MS-M12		
15:50 - 16:15	Weiguo Gao[120]	TBD
16:15 - 16:40	Yaoyu Zhang[121]	Understanding Condensation via Embedding Principle and Optimistic Estimate of Deep Neural Networks
16:40 - 17:05	Zhuosong Zhang[122]	Convergence rates for local dependent random variables
17:05 - 17:30	Jiayu Zheng[123]	On Mean-field super-Brownian motions
17:30 - 17:55	Yu Wang[124]	Phase transition in the EM scheme of an SDE driven by α-stable noises with $\alpha \in (0, 2]$
Room: E22-2009, June 30 MS-M13		
16:00 - 16:30	Zhi Liu[125]	Multivariate high frequency realized volatility for sluggish trading
16:30 - 17:00	Jia Zhai[126]	Paths, Pasts, or More – a High- Frequency Perspective in Cryptocurrency Volatility
17:00 - 17:30	Zhipeng Huang[127]	Generalized convergence for the Deep BSDE method
17:30 - 18:00	Fengyan Wu[128]	Total value adjustment of option valuation under CGMY Processes

Room: E22-2014, June 30 Contributed talk		
16:00 - 16:30	Shinya Uchiumi[129]	A finite element / spectral mixed approximation for the Stokes problem
16:30 - 17:00	Feng-Nan Hwang[130]	Insight of nonlinear elimination preconditioning from ODE theory viewpoint
17:00 - 17:30	Kensuke Aihara[131]	Cross-interactive residual smoothing for reducing the residual gap of block Lanczos- type iterative methods
17:30 - 18:00	Sennosuke Watanabe[132]	Continuous, discrete and ultra-discrete Burgers equation derived through the correlated random walk
Room: E22-2013, June 30 MS-M01		
16:00 - 16:25	Ting Gao[133]	Functional Tipping Indicators in Stochastic Dynamical Systems vis Schrodinger Bridge
16:25 - 16:50	Yixiao Lu[134]	Hermite spectral method for multi-species Boltzmann equation
16:50 - 17:15	Zhiqing Xu[135]	Understand how initialization affects inference ability of transformer network via network condensation
17:15 - 17:40	Yiwen Lin[136]	An asymptotic-preserving-based bi-fidelity method for kinetic-fluid modeling of mixture flows with distinct particle sizes and uncertainties
17:40 - 18:05	Yi Yu[137]	A Quasi Monte Carlo-Based Domain Decomposition Preconditioner for Efficiently Solving the Helmholtz Equation in Random Media
18:05 - 18:30	Liu Liu[138]	On asymptotic-preserving neural networks for the semiconductor Boltzmann equation under diffusive scaling

Parallel Session IV

Morning, July 1, 2024

Room: E22-1003, July 1 MS-M03		
10:20 - 10:50	Takeshi Fukaya[139]	CholeskyQR type algorithms for tall-skinny QR factorization
10:50 - 11:20	Weiguo Gao[140]	An optimal error bound for shiftedCholeskyQR3 in oblique inner product
11:20 - 11:50	Zhigang Jia[141]	Quaternion reorthogonalization method with application to color image processing
11:50 - 12:20	Meiyue Shao[142]	Householder orthogonalization with a nonstandard inner product
Room: E22-1011, July 1 MS-M06		
10:20 - 10:50	Cheng Yuan[143]	DPK: Deep Neural Network Approximation of the First Piola- Kirchhoff Stress
10:50 - 11:20	Xiaoxue Qin[144]	A threshold dislocation dynamics method
11:20 - 11:50	Jiuyang Liang[145]	Random batch molecular dynamics method for fully periodic and quasi-2D periodic systems
11:50 - 12:20	Zecheng Gan[146]	A kernel-splitting algorithm framework for interacting particle systems under quasi-2D confinement
Room: E22-2017, July 1 MS-M07		
10:20 - 10:50	Hisashi Okamoto[147]	Non-local non-linear PDE models arising in fluid mechanics
10:50 - 11:20	Eiji Yanagida[148]	Traveling singularities in the fast-diffusion equation
11:20 - 11:50	Chien-Hong Cho[149]	On the convergence of the numerical blow-up time for a rescaling algorithm
11:50 - 12:20	Dongyuan Xiao[150]	Linear vs. nonlinear speed selection of the front propagation into unstable states
Room: E4-G068, July 1 Type Student I		
10:20 - 10:45	Zhao Ding[151]	ODE-based Sampling and Generative Models
10:45 - 11:10	Zhiyuan Lyu [152]	Density-equalizing Quasiconformal maps with applications
11:10 - 11:35	Geng Li[153]	A deep neural network framework for dynamic multi-valued mapping estimation and its applications
11:35 - 12:00	Yaxin Feng[154]	DEEP ELASTIC INTERACTION ENERGY APPROACH FOR IMAGE PROCESSING
12:00 - 12:25	Yuchen Guo[155]	Automatic Landmark Detection and Registration of Brain Cortical Surfaces via Quasi-Conformal Geometry and Convolutional Neural Networks

Room: E22-2002, July 1 MS-M11		
10:20 - 10:50	Tetsuji Tokihiro[156]	Nonlinear differential equation model for vascular network
10:50 - 11:20	Tatsuki Mori[157]	Bifurcation structure of stationary solutions of a 1D Phase-Field equation
11:20 - 11:50	Kohei Higashi[158]	Exact solutions to nonlinear partial differential equations with singular integral terms and their application to traffic flow
11:50 - 12:20	Takiko Sasaki[159]	The blow-up boundary for systems of semilinear wave equations
Room: E22-2009, July 1 MS-M13		
10:20 - 10:50	Hongkun Zhang[160]	Conservation laws for Hamiltonian systems
10:50 - 11:20	Jinchao Feng[161]	Data-driven model selections of interacting particle dynamics via Gaussian processes with uncertainty quantification
11:20 - 11:50	Gangnan Yuan[162]	Deep Learning method for coun- terparty risk of high-dimensional options
11:50 - 12:25	-	-
Room: E22-2014, July 1 Contributed Talk		
10:20 - 10:50	Matiasde Jong van Lier[163]	Topological filtering of a signal over a network
10:50 - 11:20	Sebastian Graiff[164]	Analyzing representational capacity: determinantal point processes with symmetric vs non- symmetric kernels
11:20 - 11:50	Sitai Li[165]	A comprehensive study on zero- background solutions of the sharp-line Maxwell-Bloch equations

References

[1] **Multigrid parallel-in-time methods for nonlinear hyperbolic PDE systems**.

Hans De Sterck. University of Waterloo.

Abstract: Sequential time-stepping using only spatial parallelism is becoming a computational bottleneck because the world's largest parallel computers now have millions of parallel processor cores due to stagnating processor speeds. In this context, parallelization in time can provide additional concurrency leading to further speedups. Parallel-in-time methods have been demonstrated to work well for parabolic PDEs, but remain a challenge for hyperbolic PDEs. In this talk, we present new developments for the multigrid reduction-in-time (MGRIT) parallel-in-time method that solve nonlinear hyperbolic PDEs and hyperbolic systems in a small number of iterations with convergence factors independent of mesh resolution. Crucial ingredients include suitable coarse-grid operators, linearizations, and block preconditioners for systems. Results are presented for linear advection and linear acoustic systems, and for the nonlinear Burgers equation, shallow water equations and compressible Euler equations with shocks.

[2] **Deep Approximation via Deep Learning**.

Zuowei Shen. National University of Singapore.

Abstract: The primary task of many applications is approximating/estimating a function through samples drawn from a probability distribution on the input space. The deep approximation is to approximate a function by compositions of many layers of simple functions, that can be viewed as a series of nested feature extractors. The key idea of deep learning network is to convert layers of compositions to layers of tuneable parameters that can be adjusted through a learning process, so that it achieves a good approximation with respect to the input data. In this talk, we shall discuss mathematical theory behind this new approach and approximation rate of deep network; we will also show how this new approach differs from the classic approximation theory, and how this new theory can be used to understand and design deep learning networks.

[3] **AI-enabled Differ- entiable Methods for Computer- aided Design and Engineering**.

Jingrun Chen. University of Science and Technology of China.

Abstract: The integration of computer-aided design (CAD) and computer-aided engineering (CAE) requires solving partial differential equations (PDEs) over complex geometries and optimizing quantities of interest with respect to the geometric parameterization under physical constraints. In this talk, we will delve into artificial intelligence (AI)-enabled differentiable methods in CAD and CAE, which have the potential to address these challenges. In particular, we will introduce: (1) the random feature method for solving PDEs, which promises to be a robust method in terms of accuracy and geometric complexity; (2) AI-enabled differentiable method, which automates the shape optimization process with minimal human efforts.

[4] **Some Computational Mathematics Challenges in HUAWEI Engineering Applications**.

Yuwei Fan. Huawei Technologies · Theory Lab.

Abstract: In the high-tech engineering applications, computational mathematics is the key to solve many engineering problems. How to transform engineering problems into mathematical problems, how to use computational mathematics tools to solve them, and how to apply solutions to engineering problems to gain benefits are the main contents of our research. This report is based on the construction of a high-performance math library, and by looking at the academic community, the industry and the ourself, and combining with the current trends in mathematics and computer technology. We would discuss and propose some mathematical questions, and some of them will be explained in detail in combination with our previous research work, and the mathematical thinking and difficulties behind these problems will be explained.

[5] **Ultradiscrete integrable systems and eigenvalue algorithms over min-plus algebra**.

Akiko Fukuda. Shibaura Institute of Technology.

Abstract: The min-plus algebra is a commutative and idempotent semiring with two binary operations: 'min' and '+' in the set of real numbers with positive infinity. In this algebraic framework, a matrix eigenvalue represents an average weight of circuits of the associated directed graph. On the other hand, several numerical algorithms are known to originate from discrete integrable systems, which can be transformed into equations over min-plus algebra through a limiting procedure called ultradiscretization. This talk explores various numerical algorithms over the min-plus algebra related to ultradiscrete integrable systems. Additionally, it unveils unexpected relationships among algorithms through ultradiscretization.

[6] **PDE-constrained shape optimization: shape gradients, convergence and well-posedness**.

Wei Gong. Academy of Mathematics and Systems Sciences Chinese Academy of Sciences.

Abstract: In this talk I will introduce our recent results on PDE-constrained shape optimization. First, we proposed a modified boundary type shape gradient formula for shape optimization of Dirichlet problems and gave a new error analysis for Neumann problems, which improved the known results numerically and theoretically. Second, we gave a convergence analysis of evolving finite element approximations to shape gradient flows, which is a coupled nonlinear PDE system consisting of the state, the adjoint, the velocity and the flow map equations. In this approach, the constraint partial differential equations could be solved by finite element methods on a domain with a solution-driven evolving boundary. Third, we studied the well-posedness of shape optimization approaches for solving Bernoulli free boundary problems. Previous works showed that tracking Neumann data is well-posed while tracking Dirichlet data is not. In this work we show that tracking Dirichlet data is also well-posed by choosing a stronger norm for the Dirichlet data.

[7] **Designing a Kinematic Chain through Point Configuration on the Two Sphere**.

Shizuo Kaji. Kyushu University.

Abstract: We consider a ring of tetrahedra interconnected by opposite edges as hinges, forming a structure known as a Kaleidocycle. This intriguing object, foldable from a sheet of paper, rotates like a bubble ring. We model the Kaleidocycle as a discrete space curve with constant torsion, and identify its configuration space as a certain point configuration on the two sphere. Then, we describe its motion by the flow generated by a semi-discrete integrable system. Through numerical experiments, we present open problems, highlighting disparities between discrete and continuous geometry.

[8] **Structure-Preserving Doubling Algorithms for Nonlinear Matrix Equations**.

Yueh-Cheng Kuo. National Chengchi University.

Abstract: Structure-Preserving Doubling Algorithms (SDAs) are efficient al- gorithms for solving Riccati-type matrix equations. However, the breakdowns may occur in SDAs. To remedy this drawback, we first introduce Ω-symplectic forms (Ω-SF), consisting of symplectic matrix pairs with a Hermitian parametric matrix Ω. Based on Ω-SFs, we develop modified SDAs (MSDAs) for solving the associated Riccati-type equations. MSDAs generate sequences of symplectic matrix pairs in Ω-SFs and prevent breakdowns by employing a reasonably selected Hermitian matrix Ω. In practical implementations, we show that the Hermitian matrix Ω in MSDAs can be chosen as a real diagonal matrix that can reduce the computational complexity. The numerical results demonstrate a significant improvement in the accuracy of the solutions by MSDAs.

[9] **Surface Reconstruction from Point Cloud**.

Myungjoo Kang. Seoul National University.

Abstract: In this presentation, we introduce a sophisticated deep learning approach to reconstruct surfaces from unorganized point clouds. Utilizing an implicit surface representation as a level set function, our method guarantees watertight results and adapts seamlessly to various topologies. We employ the p-Poisson equation to accurately learn the signed distance function (SDF), enhancing precision through a variable splitting strategy that incorporates the SDF gradient as an auxiliary variable. Furthermore, we enforce a curl-free condition on the auxiliary variable to leverage the irrotational nature of conservative vector fields. Our numerical results demonstrate that this strategic use of partial differential equations and key vector field characteristics efficiently reconstructs high-quality surfaces without the need for prior surface knowledge.

[10] **Multilevel circulant preconditioner for high-dimensional fractional Laplacian**.

Siu-Long Lei. University of Macau.

Abstract: In a recent study, a diffusion equation with high-dimensional integral fractional Laplacian is discretized as an easy-to-implement scheme with multilevel Toeplitz structure, and a multilevel circulant preconditioner is proposed for an iterative solver. In this work, the resulting linear system is shown to be an M-matrix with multilevel off-diagonal decay, hence the difference matrix with the multilevel circulant preconditioner is shown to have spectrum weakly cluster around zero, indicating possible improvement in convergence rate of the preconditioned iterative solver.

[11] **Numerical analysis and simulation of a model for Stereolithography in 3D printing**.

KeiFong Lam. Hong Kong Baptist University.

Abstract: Stereolithography is a 3D printing technique that utilizes ultraviolet lasers to cure/solidify photosensitive liquid polymer resin in order to build objects and products in a layer-by-layer fashion. In this talk we discuss the development of a new mathematical description based on a phase field model with mechanical effects, and then present a finite element/scalar auxiliary variable numerical scheme, along with demonstrating solvability, convergence and error estimates. With supporting numerical simulations we show that capabilities of this model in capturing the physical processes occurring in stereolithography.

[12] **A data-dependent regularization method based on the graph Laplacian**.

Davide Bianchi. Sun Yat-sen University.

Abstract: Differential operators are popular choices for regularizing ill-posed problems in imaging. We investigate a variational method which embeds a graph Laplacian operator in the regularization term. The novelty of this method lies in constructing the graph Laplacian based on a preliminary approximation of the solution, which is obtained using any existing reconstruction method from the literature. As a result, the regularization term is both dependent on and adaptive to the observed data and noise. We demonstrate that this method is regularizing and stable, and it can obtain reconstructions of the ground truth solution of higher quality.

[13] **Revealing Entanglement through Low-Rank Approximation**.

Matthew M.Lin. National Cheng Kung University.

Abstract: Assessing the separation between a mixed state and its nearest separable state is challenging in quantum mechanics. In this talk, we pro-pose a dynamic system approach to address the low-rank approximation of entangled bipartite systems. This approach offers several advantages, including, a) a concise description of gradient dynamics in complex space; b) guaranteed global convergence from any initial point to a local solution; c) ensuring that combination coefficients of pure states form a probability distribution; d)dynamic adjustment of the rank. In short, the talk will cover the theory and algorithms and showcase results from numerical experiments.

[14] **Fast Newton-Noda iteration for computing the ground states of nonlinear Schr"odinger equations**.

Ching-Sung Liu. National University of Kaohsiung.

Abstract: In this talk, we present a fast Newton-Noda iteration (FNNI) to find the ground state of nonlinear Schr"odinger (NLS) equations. FNNI preserves the global and quadratic convergence properties of the original NNI, while also addressing the shortcomings associated with the halving strategy of NNI and improving the efficiency of solving linear systems. Finally, we perform several numerical experiments to validate our theoretical framework and emphasize the efficiency, robustness, and wide applicability of the proposed method.

[15] **Some equilibrium Hermitian solutions of the conjugate discrete-time algebraic Riccati equation**.

Chun-Yueh Chiang. National Formosa University.

Abstract: In this talk we consider a class of conjugate discrete-time Riccati equations (CDARE), arising originally from the linear quadratic regulation problem for discrete-time antilinear systems. Recently, we have proved the existence of the maximal solution to the CDARE with a nonsingular control weighting matrix under the framework of the constructive method. Our contribution in the work is to finding another meaningful solutions, which has received little attention in this topic. Moreover, we show that all extremes cannot be attained at the same time. It is to be expected that our theoretical results presented in this work will play an important role in the optimal control problems for discrete-time antilinear systems.

[16] **An accelerated technique for computing extremal solutions of discrete-time algebraic Riccati equations**.

Hung-Yuan Fan. National Taiwan Normal University.

Abstract: "Algebraic Riccati equations (AREs) have been extensively applied in linear optimal control problems and many efficient numerical methods were developed. The stabilizing (or almost stabilizing) solution has attracted the most attention among all Hermitian solutions of the ARE in the past works. Nevertheless, it is an interesting and challenging issue in finding the extremal solutions of AREs which play an important role in the applications. The contribution of this paper is twofold. Firstly, the existence of these extremal solutions is established under the framework of fixed-point iteration. Secondly, an accelerated fixed-point iteration (AFPI) based on the semigroup property is developed for computing four extremal solutions of the discrete-time algebraic Riccati equation. In addition, we prove that the convergence of the AFPI is at least R-suplinear with order r>1 under some mild assumptions. Numerical examples are shown to illustrate the feasibility and accuracy of the proposed algorithm.".

[17] **Exploring the Advantages of Random Feature Method in Solving PDEs: Insights from the Perspective of Optimization Difficulty**.

Chuqi Chen. Hong Kong University of Science and Technology.

Abstract: In this study, we analyze the high-precision capabilities of the random feature method for solving PDEs from the perspective of optimization difficulty. Furthermore, we extend the strategies employed in this method to the context of neural networks.

[18] **A learning framework for mapping problems via Quasiconformal geometry**.

Qiguang Chen. The Chinese University of Hong Kong.

Abstract: Many imaging problems can be formulated as mapping problems. A general mapping problem aims to obtain an optimal mapping that minimizes an energy functional subject to the given constraints. Existing methods to solve the mapping problems are often inefficient and can sometimes get trapped in local minima. An extra challenge arises when the optimal mapping is required to be diffeomorphic. In this work, we address the problem by proposing a deep-learning framework based on the Quasiconformal (QC) Teichm"uller theories. The main strategy is to learn the Beltrami coefficient (BC) that represents a mapping as the latent feature vector in the deep neural network. The BC measures the local geometric distortion under the mapping, with which the interpretability of the deep neural network can be enhanced. Under this framework, the diffeomorphic property of the mapping can be controlled via a simple activation function within the network. The optimal mapping can also be easily regularized by integrating the BC into the loss function. A crucial advantage of the proposed framework is that once the network is successfully trained, the optimized mapping corresponding to each input data information can be obtained in real time. To examine the efficacy of the proposed framework, we apply the method to the diffeomorphic image registration problem. Experimental results outperform other state-of-the-art registration algorithms in both efficiency and accuracy, which demonstrate the effectiveness of our proposed framework to solve the mapping problem.

[19] **Harmonic Beltrami Signature and Shape Prior Segmentation**.

Chenran Lin. Chinese University of Hong Kong.

Abstract: Harmonic Beltrami Signature(HBS) is a novel shape representation of 2D bounded simply-connected shapes. There exists a one-to-one correspondence between HBS and shapes up to translation, scaling and rotation. Therefore, HBS could provide shape prior information to segmentation model, offering improved performance without requiring template preprocessing, even on noisy, damaged, or occluded images.

[20] **Parallel Computation of Quasi-conformal Mappings via Conformal Welding**.

Zhipeng Zhu. The Chinese University of Hong Kong.

Abstract: In this talk, we present a novel method to apply parallel computing for accelerating the computation of quasi-conformal mappings from Riemann surfaces to the planar domain. The key idea is to use a technique called conformal welding. First, we partition a triangulated surface into several smaller parts. Then, we compute the quasi-conformal parameterizations of each of them in parallel. Next, we apply conformal welding to weld each sub-mesh to obtain the global quasi-conformal mapping. Some boundary conditions may be dealt as the final step. Applications of our algorithm include texture mappings, remeshing, and surface registration.

[21] **Deep Operator-Splitting Network for Solving PDEs**.

Xiang Yang. The Hong Kong University of Science and Technology.

Abstract: Deep neural networks (DNNs) recently emerged as a promising tool for analyzing and solving complex differential equations arising in science and engineering applications. However, the lack of physics-in-the-loop often makes it difficult to construct a neural network solver that simultaneously achieves high accuracy, low computational burden, and interpretability. In this work, focusing on a class of evolutionary PDEs characterized by decomposable operators, we show that the classical operator splitting technique can be adapted to design neural network architectures. This gives rise to a learning-based PDE solver, which we name Deep Operator-Splitting Network (DOSnet). To demonstrate the advantages of our new AI-enhanced PDE solver, we train and validate it on several types of operator-decomposable differential equations, and experimental results show that our model has better accuracy and lower computational complexity than numerical schemes and the baseline DNNs.

[22] **Contact Boundary Condition for Dislocation Dynamics Simulation in Crystal**.

Shuyang Dai. Wuhan University.

Abstract: The movement of dislocations and the corresponding crystal plastic deformation are highly influenced by the interaction between dislocations and nearby free surfaces. The boundary condition for inclination angle which indicates the relation between a dislocation line and the surface is one of the key ingredients in the dislocation dynamic simulations. We present a systematical study on angle by molecular static simulations in BCC-irons. We study the inclination angle by using molecular dynamic simulations. A continuum description of inclination angle in both static and dynamic cases is derived based on Onsager's variational principle. We show that the results obtained from continuum description are in good agreement with the molecular simulations.

[23] **Force-based blended atomistic to higher order continuum coupling method**.

Hao Wang. Sichuan University.

Abstract: Atomistic/continuum(a/c) coupling methods are a class of multiscale schemes for coupling an atomistic description of a solid to a matching continuum elasticity description. Higher-order continuum model is a nonlinear elastic model with higher accuracy than the Cauchy-Born model. In this talk, we present the construction and error analysis of a/c coupling method with higher-order continuum model in one dimension. We will start from the classical a/c coupling methods with Cauchy-Born model, and extend the analysis to higher-order continuum coupling methods. We will explain why the a/c coupling method based on blended energy may improve the total accuracy, and therefore adopt blended force-based a/c coupling method to improve the accuracy. We will present numerical experiments to illustrate our theoretical analysis.

[24] **Simulation Method of Microscale Fluid-Structure Interactions: Diffuse-Resistance-Domain Approach**.

Xinpeng Xu. Guangdong Technion Israel Institute of Technology.

Abstract: We consider the microscale fluid-structure interactions (mFSI) from different fields such as particle focusing in microchannels from microfluidics, deformable objects suspending in micro-swimmer suspensions from microbiology, and two-phase flows on solid surfaces from various contexts, e.g., microscale manufacturing, and geophysics, etc. For this purpose, we propose and validate a generic monolithic direct numerical simulation

(DNS) approach – Diffuse- Resistance-Domain (DRD) approach [1] for mFSI in multicomponent multiphase flows. This approach overcomes major challenges of simulating mFSI where we use diffuse-interface models for fluid-fluid interfaces and apply fluid-solid interfacial conditions via smooth interpolations of dynamic-resistance coefficients across interfaces [1-3]. Some interesting applications in microfluidics, active matter, and porous media flows are presented as examples. The DRD approach is extensible and reusable, making it suitable for simulating complex mFSI involving multi-physics multi-field couplings. This generic DNS approach offers a promising tool for understanding physical mechanisms, controlling microscale fluids, and optimizing engineering processes in areas like microfluidics, additive manufacturing, and biomedical engineering.

[25] **Numerical Methods for Eigenvalue Problems**.

Hehu Xie. Academy of Mathematics and Systems Sciences Chinese Academy of Sciences.

Abstract: In this talk, we will introduce numerical methods for solving algebraic and differential operators' eigenvalue problems. For different type of eigenvalue problems, we will introduce our techniques and software from discretization method, algebraic eigensolver. Furthermore, for solving high dimensional eigenvalue problem, we also develop a type of tensor-neural-network-based machine learning method. This method does not need the Monte Carlo process and can arrive high accuracy.

[26] **DUE: Deep Learning for Modeling Unknown Equations**.

Kailiang Wu. Southern University of Science and Technology.

Abstract: This talk will introduce effective methods for learning unknown time-dependent differential equations from measurement data. We will explore the importance of using many short bursts of trajectory data instead of a few long trajectories. We will present several data-driven modeling strategies using deep neural networks. It will be shown that residual networks are particularly suitable for equation discovery, as they can produce an exact time integrator for numerical predictions. Additionally, the deep learning of unknown partial differential equations in modal or nodal spaces will be discussed, along with recent advances in structure-preserving learning approaches for unknown equations. Finally, we will introduce a deep learning library, named "DUE", for modeling unknown differential equations.

[27] **Development and Reflection on Domestic Scientific Computing and System Simulation Software**.

Dao Xiang. Beitaizhenhuan (Chongqing) Technology Company.

Abstract: Baltamatica is the first scientific computing software with complete independent intellectual property rights in China. After breaking through and realizing the core root technology, it has formed an interpretive programming language and supports personnel training and scientific development in various fields through scientific computing capabilities. Baltamatica provides scientific computing, visualization and interactive programming environment, with a rich underlying mathematical function library. it supports numerical calculation, data analysis, data visualization, data optimization, algorithm development. At present, there are more than 300 universities on trial. The users cover automotive, aerospace, production and help industrial enterprises based on their own scenario needs in scientific calculation and industrial simulation.

[28] **Multi-mesh adaptive finite element methods in electronic structure calculations**.

Yang Kuang. Guangdong University of Technology.

Abstract: Multi-mesh methods have been devised to improve the accuracy of electronic structure calculations while decreasing computational expenses. Simultaneously employing independent mesh adaptations, however, is not trivial, as it requires meticulous consideration to avoid the loss of accuracy and ensure efficient implementation. These requirements highlight the significance of skillfully designing and implementing the mesh management mechanism, specifically the data structure within the software. In this presentation, we aim to delve into these challenges, illustrate how the adaptive finite element package AFEPack addresses them, and demonstrate the effectiveness of the multi-mesh adaptive method in electronic structure calculations.

[29] **A Reduced Order Model Enhanced Iterative Solver for Parametric Radiative Transfer Equation**.

Zhichao Peng. The Hong Kong University of Science and Technology.

Abstract: Radiative transfer equation (RTE) is a kinetic equation modeling particles propagating through and interacting with a background medium. Applications, such as uncertainty quantification, medical imaging, and shape optimization, require solving RTE many times for various parameters. Source Iteration (SI) with Diffusion Synthetic Acceleration (DSA) is a popular iterative solver for RTE. DSA can be seen as a preconditioning step to accelerate the convergence. However, DSA does not utilize low rank structures with respect to parameters of the parametric problem. Furthermore, when the underlying problem is far from its diffusion limit, DSA may become less effective, as it uses the diffusion limit to approximate a kinetic correction equation. To address these issues, we exploit data-driven reduced order models (ROMs), which leverage low-rank structures concerning parameters, to enhance SI. ROMs can provide not only a better initial guesses, but also an efficient synthetic acceleration strategy built on the kinetic description.

[30] **Unconditionally energy stable gradient flow schemes for shape optimization in Navier-Stokes flow**.

Jiajie Li. Shanghai Jiaotong University.

Abstract: We study the shape optimization constrained by the incompressible Navier-Stokes equations using a phase field model. The novel stabilized semi-implicit schemes of the gradient flow in Allen-Cahn and Cahn-Hilliard types are proposed for solving the resulting optimal control problem. The unconditional energy stability is provably proven for the gradient flow schemes in continuous and discrete spaces with the Lipschtiz continuity of the state and adjoint variables. Numerical experiments of Computational Fluid Dynamics in 2d and 3d show the effectiveness and robustness of the optimization algorithms proposed.

[31] **A novel shape optimization approach for the source identification of elliptic equations**.

Ziyi Zhang. Academy of Mathematics and Systems Sciences Chinese Academy of Sciences.

Abstract: In this talk we present a novel shape optimization approach for the source identification of elliptic equations. This model problem comes from two application backgrounds, one is the actuator placement while the other is the regularized least-squares formulation of source identifications. We aim at identifying the source location and strength simultaneously. The problem is reformulated as a shape optimization problem by viewing the first order optimality system as the state equation. We design a shape gradient descent method based on the shape derivative, while numerical experiments that confirm the result will be presented.

[32] **A non-conventional shape optimization method for shape identification problems**.

Julius FergyRabago. Kanazawa University.

Abstract: "A non-conventional approach to shape optimization is proposed for resolving overdetermined boundary value problems characterized by free boundary problems or inverse geometry problems. The core principle of the method involves transforming the over-specified problem into a complex boundary value problem. This transformation incorporates a complex Robin boundary condition, derived from the coupling of Dirichlet and Neumann boundary conditions along the accessible boundary. To obtain the solution to the shape problem, the cost function is optimized, constructed based on the imaginary part of the solution across the entire domain. Subsequently, the shape gradient of this cost function is computed to iteratively solve the optimization problem using a Sobolev gradient descent algorithm. The feasibility of the method is demonstrated through numerical experiments conducted in both two and three spatial dimensions, considering fluid flows governed by Stokes flow. This talk is based on some joint works with Hirofumi Notsu (Kanazawa University, Japan) and Lekbir Afraites (Sultan Moulay Slimane University, Morocco).".

[33] **A mechanism-driven reinforcement learning framework for shape optimization of airfoils**.

Jingfeng Wang. University of Macau.

Abstract: In this paper, a novel mechanism-driven reinforcement learning framework is proposed for airfoil shape optimization. To validate the framework, a reward function is designed and analyzed, from which the equivalence between the maximizing the cumulative reward and achieving the optimization objectives is guaranteed theoretically. To establish a quality exploration, and to obtain an accurate reward from the environment, an efficient solver for steady Euler equations is employed in the reinforcement learning method. The solver utilizes the Bézier curve to describe the shape of the airfoil, and a Newton-geometric multigrid method for the solution. In particular, a dual-weighted residual-based h-adaptive method is used for efficient calculation of target functional. To effectively streamline the airfoil shape during the deformation process, we introduce the Laplacian smoothing, and propose a Bézier fitting strategy, which not only remits mesh tangling but also guarantees a precise manipulation of the geometry. In addition, a neural network architecture is designed based on an attention mechanism to make the learning process more sensitive to the minor change of the airfoil geometry. Numerical experiments demonstrate that our framework can handle the optimization problem with hundreds of design variables. It is worth mentioning that, prior to this work, there are limited works combining such high-fidelity partial differential equatons framework with advanced reinforcement learning algorithms for design problems with such high dimensionality.

[34] **Fast Elasticity Parameters Estimating with Iterative Choice of Regularization Parameter and Continuation Method**.

Yunjue Gu. Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences.

Abstract: In the study of human blood flow hemodynamics, elastic models are widely used to understand the stress and strain distributions within arterial walls and tissues. However, directly measuring elasticity parameters like Poisson's ratio and Young's modulus in clinical settings presents challenges. Instead, displacement can be measured using medical imaging methods, offering a pathway to estimate elasticity parameters by solving an inverse problem. In this talk, we aim to estimate elasticity parameters in scenarios with both spatially constant and variable coefficients. Convergence poses a significant challenge in variable coefficient cases due to the increased degrees of freedom in the inverse problem. To address this, we propose an iterative approach for the update of the regularization parameter and a continuation method, which reduces the sensitivity to the initial guess of the iterative solver and ensures rapid convergence across different levels of noise. Furthermore, we examine the influence of various objective functions and regularization terms on the solution outcomes in two scenarios: the compressible scenario which recovers two parameters simultaneously, and the nearly incompressible scenario where Poisson's ratio is approximately 0.5.

[35] **Quantitative Theory for Richtmyer-Meshkov Instability in Compressible Fluids**.

Qiang Zhang. Beijing Normal University.

Abstract: When a shock hits a material interface between two compressible fluids of different densities, unstable bubbles (light fluids penetrating into heavy ones) and spikes (heavy fluids penetrating into light ones) develop. This phenomena is known as the Richtmyer-Meshkov instability. Theoretical treatment of the Richtmyer-Meshkov instability in compressible fluids is a challenging task due to the presence of compressibility of the fluids, the nonlinearity in the dynamics and the instability of the material interface. We present a quantitative theory for the spikes and bubbles in Richtmyer-Meshkov instability in compressible fluids based on the methods of the asymptotic analysis and asymptotic matching. The theory provides analytical predictions for the growth rate and amplitude of spikes and bubbles between two compressible fluids of arbitrary density ratios and over the entire time domain from early to late times. The theoretical predictions are in excellent agreement with data from several independent numerical simulation methods and experiments.

[36] **Positivity-preserving finite volume schemes for radiation diffusion equations on general meshes**.

Shuai Su. Beijing University of Technology.

Abstract: Radiation diffusion equations arise in a wide range of physical applications such as astrophysics and inertial confinement fusion. Two key ingredients in constructing their numerical schemes are both positivity-preserving property and good accuracy for discontinuous and/or anisotropic problems on arbitrary distorted meshes. This talk will introduce our recent research progress including positivity-preserving finite volume schemes, theoretical analysis, and numerical applications.

[37] **Acceleration of self-consistent field iteration for electronic structure calculations**.

Fei Xu. Beijing University of Technology.

Abstract: Electronic structure calculations involve complicated nonlinear models that require iterative algorithms to obtain approximate solutions. However, for complex molecular systems, the classical self-consistent field iteration does not converge or converges slowly. In order to improve the efficiency of self-consistent field iteration, we proposes a new accelerating algorithm. The main idea is to fit out a polynomial based on the error of the derived approximate solution, and then extrapolate the error into zero to obtain a new approximation. In each iteration step, the efficiency can be further improved through transforming the eigenvalue problem into a linear boundary value problem and a small-scale correction equation. The developed scheme can not only be applied to electronic structure calculation but also to accelerate the nonlinear iterations of other nonlinear equations. Some numerical results for electronic structure calculation and general nonlinear equations are presented to validate the efficiency of the new method.

[38] **Maintaining the Productivity of Co-culture Systems in the Face of Environmental Change**.

Angelyn Lao. De La Salle University.

Abstract: Co-culture systems have the potential to address food security concerns by effectively increasing the production of crops and animal protein in a sustainable manner, without the need for additional land resources. Our research demonstrates how an optimization model utilizing ecological network analysis can identify resilient co-culture strategies through the management of key species. Simulations conducted on a hybrid production system suggest that varying ecological network structures can still achieve comparable levels of productivity.

[39] **Analysis of the 9th Chebyshev Method in Non-Convex Non-Smooth Optimization Problems**.

Yangjia Bao. Musashino University.

Abstract: Some continuous optimization methods can be viewed as numerical methods applied to ordinary differential equations, and the derivation and analysis of optimization methods have been conducted from the perspective of numerical analysis. Ushiyama, Sato and Matsuo (2022) proposed an efficient method based on numerical methods with a wide stable region for convex function optimization. On the other hand, Riis, Ehrhardt and Quispel (2022) examined optimization problems of non-differentiable and non-convex functions, and devised optimization methods to monotonically decrease the objective function. In this talk, we propose a method that combines the method proposed in Ushiyama, Sato and Matsuo (2022) with the method proposed in Riis, Ehrhardt, Quispel (2022), and prove that the proposed method monotonically decreases the objective function. Additionally, we present the implementation results of this method.

[40] **Vector Field Reconstruction on Convex Polygonal Domains based on Hyperplane Arrangement**.

Junyan Chu. Kyushu university.

Abstract: We consider the problem of reconstructing a vector field from sparsely observed data in scenarios like fluidic materials or particles within a convex polygonal domain P. We demand the vector field to be tangent to the polygonal boundary ∂P. In this work, we introduce a novel scheme for reconstructing a vector field on a convex polygonal domain by a polynomial vector field, leveraging the ideas from the theory of hyperplane arrangement. Given a degree upper bound k and observed vectors at finite points in the domain, our algorithm computes a degree k polynomial vector field that interpolates the observations in a least squares sense while satisfying the boundary condition exactly. Additionally, the algorithm can determine a minimal degree polynomial vector field within a specified error threshold.

[41] **On Finite Volume Methods for a Class of Variational Inequalities Arising in Hydrodynamics**.

Feifei Jing. Northwestern Polytechnical University.

Abstract: Finite volume methods are introduced to solve a class of variational inequalities of the second kind, which are governed by the incompressible Stokes/Navier–Stokes equations under nonlinear slip boundary conditions of friction type. The particularity locates in the approximation to the subdifferential term which is caused by the nonlinear constraint condition. Instead of directly integrating by parts of the original equations on the dual volume, the numerical schemes, followed by proper numerical integration formulas on the slip boundary, are derived by starting from the saddle point equation problem. Equivalence to the finite element forms, stability and solvability of the numerical schemes are shown and optimal order error estimates are derived. Numerical results are reported to demonstrate the theoretical findings.

[42] **Parallel-in-Time Multilevel Krylov Method**.

Yogi Erlangga. Zayed University.

Abstract: Parareal [1] has opened ways of computing solution of evolutionary differential equations in a non-traditional way: instead of sequentially marching in time from the initial time, Parareal algorithm allows computation of solutions in parallel over time subintervals independently. Connection between time subintervals is established through sequential solution using larger time step, which is used to define and improve the initial solution for each time subinterval. A few interpretations of Parareal have been derived, and one of them links Parareal with a special type of multigrid. The latter paves the way to the development of parallel-in-time multigrid methods, such as MGRIT [2]. It is also possible to construct a parallel-in-time method based on Krylov methods with projection-like preconditioners. Out of several possible implementations, this talk focuses on shift operator introduced in [3], which, like multigrid, allows multilevel solution procedure in a stable way. In the method, detailed in [4], a special time restriction and interpolation operator are proposed to coarsen the time grid and to map functions between fine and coarse time grids. In this case, the resulting Galerkin coarse-grid system can be interpreted as time integration of an equivalent differential algebraic equation associated with a larger time step and a modified θ-scheme. A perturbed coarse time-grid matrix is used on the coarsest level to decouple the coarsest-level system, allowing full parallelization of the method. Within this framework, spatial coarsening can be included in a natural way, reducing further the size of the coarsest grid problem to solve. Numerical results are presented for the 1- and 2-dimensional heat equation using simulated parallel implementation, suggesting the potential computational a significant speed-up relative to the single-processor implementation and the sequential θ-scheme. References [1] J.-L. Lions, Y. Maday, and G. Turinici, A parareal in time discretization of PDEs, C.R. Acad. Sci. Paris, Serie I, 332 (2001), pp. 661–668. [2] R. D. Falgout, S. Friedhoff, TZ. V. Kolev, S. P. MacLachlan, and J. B. Schroder, Parallel time integration with multigrid, SIAM J. Sci. Comput. 36 (2014), pp. C635–C661. [3] Y.A. Erlangga and R. Nabben, Multilevel projection-based nested Krylov iteration for boundary value problems, SIAM J. Sci. Comput. 30 (2008), pp. 1572–1595. [4] Y.A. Erlangga, Parallel-in-time Multilevel Krylov Methods: A Prototype, https://arxiv.org/abs/2401.00228 (2023).

[43] **Self-generated magnetic field coupling Radiation-hydrodynamic numerical simulations In ICF**.

Rong Yang. Institute of Applied Physics and Computational Mathematics.

Abstract: Aiming at the problem of self-generated magnetic field in ICF laser-heated plasma, the numerical simulation algorithm of self-generated magnetic field and radiation hydrodynamics equations is presented based on two-dimensional arbitrary quadrilateral grids. The coupling algorithms are presented. It includes differential operator splitting method, anisotropic magnetic diffusion scheme, convection diffusion scheme and high-accuracy interpolation method, etc. The correctness of the program and algorithm is verified by several typical Benchmark examples. The simulation of typical ICF application models give qualitative and reasonable magnetic and temperature distribution.

[44] **Radiation-hydrodynamics with a high-order, low-order method applied in ICF implosion simulation**.

Shuanggui Li. Institute of Applied Physics and computational mathematics.

Abstract: In this paper, in order to achieve algorithmic acceleration of radiation-hydrodynamics simulations, we incorporating the newly developed HOLO (High-Order, Low-order) method into the Eulerian radiation-hydrodynamics framework LARED-S code to accelerate the convergence of absorption-reemission physics for ICF implosion simulation. By starting from the multigroup thermal radiative diffusion equations, we derive a discretely consistent energy balance equation, the frequency-integrated LO system. Coupling the discreted LO radiation system with electron and ion energy equations, the reemission source term is computed implicitly and get predicted electronic temperature, which is used for the HO solver. The main advantage of our scheme is that this predictor-corrector approach provides acceptable accuracy without iterating to convergence. We test the approach on challenging 2D ICF implosion problems and demonstrate algorithmic speedups.

[45] **Numerical method for the crack problem with a Signorini-type contact condition on a linear combination of displacement and velocity**.

Guanyu Zhou. University of Electronic Science and Technology of China.

Abstract: We consider the finite element approximation to the dynamic of a linear elastic body with a crack. Two contact conditions are imposed on the crack. The tangential velocity is subject to the Tresca friction law. At the same time, in the normal direction, we enforce a Signorini-type condition involving a linear combination of normal displacement and normal velocity. For semi-discretization, we use the regularization approaches to prove the well-posedness and establish the convergence analysis. We present a fully-discretization scheme, demonstrate the well-posedness using the regularization approaches and monotone theory, and obtain the error estimates. To solve the variational inequality, we propose the Uzawa algorithm to treat the normal and tangential contact conditions. Several numerical experiments are carried out to test the accuracy of the fully-discrete scheme and the efficiency of the projection algorithm.

[46] **The Initial Value Problem for the Equations of Motion of Fractional Compressible Viscous Fluid**.

Shu Wang. Beijing University of Technology.

Abstract: In this talk we consider the initial value problem to the fractional compressible isentropic generalized Navier-Stokes equations for viscous fluids with one Levy diffusion process in which the viscosity term appeared in the fluid equations is described by the nonlocal fractional Laplace operator. We give one detailed spectrum analysis on a linearized operator and the decay law in time of the solution semigroup for the linearized fractional compressible isentropic generalized Navier-Stokes equations around a constant state by the Fourier analysis technique, which is shown that the order of the fractional derivatives plays a key role in the analysis so that the spectrum structure involved here is more complex than that of the classical compressible Navier-Stokes system. Based on this and the elaborate energy method, the global-in-time existence and one optimal decay rate in time of the smooth solution are obtained under the assumption that the initial data are given in a small neighborhood of a constant state.

[47] **A PML method for signal-propagation problems in axon**.

Xue Jiang. Beijing University of Technology.

Abstract: This talk is focused on the modelling of signal propagations in myelinated axons. Based on reasonable assumptions on the medium properties, we derive a two-dimensional neural-signaling model in cylindrical coordinates from the time-harmonic Maxwell's equations. The well-posedness of model is established upon Dirichlet boundary conditions at the two ends of the neural structure and the radiative condition in the radial direction of the structure. Using the perfectly matched layer (PML) method, we truncate the unbounded background medium and propose an approximate problem on the truncated domain. The well-posedness of the PML problem and the exponential convergence of the approximate solution to the exact solution are established. Numerical experiments are presented to demonstrate the theoretical results and the efficiency of our methods to simulate the signal propagation in axons.

[48] **A numerical study for deformation-induced amorphization**.

Yuntong Huang. The Hong Kong University of Science and Technology.

Abstract: Amorphization due to severe plastic deformation has been discovered in various crystalline materials. Despite its importance, developing a rigorous and general theory of strain-induced amorphization remains a significant challenge due to the intricate nature of modeling microstructural changes and deformation mechanisms. This study proposes a novel model integrated with elastic-plastic theory to shed light on shear-induced amorphization in nanocrystalline alloys. Our model incorporates the martensite transformation of the austenite phase under large plastic deformation, followed by the intensification of crystal fracture on the martensite phase to form an amorphous phase. Our simulations suggest that amorphous nucleation is more likely to occur in highly-distorted regions, such as shear bands, and that the critical plastic strain for amorphization increases as grain size grows. These observations align well with the experimental findings, indicating that our phase-field model captures the physical picture of shear-induced amorphization and can predict the threshold for amorphization.

Overall, our work offers valuable insights into shear-induced amorphization and paves the way for enhancing the understanding of amorphous materials and fostering the development of more precise and comprehensive models for investigation.

[49] **A nnU-Net-Based Brain Tumor Segmentation via Optimal Mass Transportation Pre-processing**.

Tsung-Ming Huang. National Taiwan Normal University.

Abstract: In this talk, we would like to introduce a novel 2-phase nnU-Net-based OMT framework to increase the ratio of brain tumors using optimal mass transportation (OMT). Moreover, due to the scarcity of training data, we change the density function by different parameters to increase the data diversity. For the post-processing, we propose an ensemble procedure by averaging the probabilities of Phase I and Phase II and choosing the result with the highest aggregation probability as the predicted label. The lesion-wise Dice scores of the whole tumor (WT), tumor core (TC), and enhanced tumor (ET) regions for online validation computed by nnU-Net were 0.9039, 0.8692, and 0.8529, respectively.

[50] **Data-Driven Stochastic Dynamics — Extracting Governing Laws & Detecting Critical Transitions**.

Jinqiao Duan. Great Bay University.

Abstract: The interaction of uncertainty and nonlinearity in complex systems is leading to fascinating dynamical phenomena, such as critical transitions between qualitatively different dynamical regimes. The availability of data and machine learning tools enables improved investigation of stochastic dynamics, especially in high dimensional and multiscale situations. The speaker will overview recent advances in extracting stochastic governing laws and in detecting the most probable transition pathways between metastable regimes.

[51] **Reconstruction of dynamical systems without time label**.

Zuoqiang Shi. Tsinghua University.

Abstract: In this talk, we study the method to reconstruct dynamical systems from data without time labels. Data without time labels appear in many applications, such as molecular dynamics, single-cell RNA sequencing, etc. Reconstruction of dynamical system from time sequence data has been studied extensively. However, these methods do not apply if time labels are unknown. Without time labels, sequence data becomes distribution data. Based on this observation, we propose to treat the data as samples from a probability distribution and try to reconstruct the underlying dynamical system by minimizing the distribution loss, sliced Wasserstein distance more specifically. Extensive experiment results demonstrate the effectiveness of the proposed method.

[52] **On one-dimensional Mckean-Vlasov stochastic variational inequalities**.

JingWu. Sun Yat-sen University.

Abstract: In this work we establish the existence and uniqueness of a strong solution for one-dimensional Mckean-Vlasov stochastic variational inequalities when the diffusion coefficient is locally Hölder continuity w.r.t. the state. Tamed Euler approximation is also discussed.

[53] **Nonlinear Expectation Inference for the Uncertainty Quantification**.

Jiayu Zhai. Shanghaitech University.

Abstract: Most existing inference methods for the uncertainty quantification of nonlinear inverse problems need repetitive runs of the forward model which is computationally expensive for high-dimensional problems, where the forward model is expensive and the inference need more iterations. These methods are generally based on the Bayes' rule and implicitly assume that the probability distribution is unique, which is not the case for scenarios with Knightian uncertainty. In the current study, we assume that the probability distribution is uncertain, and establish a new inference method based on the nonlinear expectation theory for 'direct' uncertainty quantification of nonlinear inverse problems. The uncertainty of random parameters is quantified using the sublinear expectation defined as the limits of an ensemble of linear expectations estimated on samples. Given noisy observed data, the posterior sublinear expectation is computed using posterior linear expectations with highest likelihoods. In

contrary to iterative inference methods, the new nonlinear expectation inference method only needs forward model runs on the prior samples, while subsequent evaluations of linear and sublinear expectations requires no forward model runs, thus quantifying uncertainty directly which is more efficient than iterative inference methods. The new method is analysed and validated using 2D and 3D test cases of transient Darcy flows.

[54] **Exploring the Optimal Choice for Generative Processes in Diffusion Models**.

Yu Cao. Shanghai Jiao Tong University.

Abstract: The diffusion model has shown remarkable success in computer vision, but it remains unclear whether the ODE-based probability flow or the SDE-based diffusion model is more superior and under what circumstances. Comparing the two is challenging due to dependencies on data distributions, score training, and other numerical issues. In this talk, we will discuss a mathematical approach for this problem by considering two limiting scenarios: the zero diffusion (ODE) case and the large diffusion case. We will demonstrate that the time distribution of the score training error will determine the optimal dynamics in terms of minimizing the sampling error in the continuous-time setting. Numerical validation of this phenomenon is provided using various benchmark distributions, as well as realistic datasets.

[55] **Weak Generative Sampler to Efficiently Sample Invariant Distribution of Stochastic Differential Equation**.

Zhiqiang CAI. City University of Hong Kong.

Abstract: "Sampling invariant distributions from an Ito diffusion process remains a significant challenge in the field of stochastic simulation. Traditional numerical solvers for stochastic differential equations demand both a fine step size and a lengthy simulation period, which results in the generation of temporally correlated samples. Present deep learning-based solvers primarily aim to determine the invariant probability density function using deep neural networks by solving the stationary Fokker–Planck equation. However, they typically do not address the problem of sampling directly from the computed density function. In this work, we introduce a framework utilizing a weak generative sampler (WGS) to directly generate independent and identically distributed (iid) samples from a transformation map derived from the stationary Fokker–Planck equation. Our proposed loss function, rooted in the weak form of the Fokker–Planck equation, seamlessly integrates the use of normalizing flows to characterize the invariant distribution and to facilitate sample generation from the base distribution. Distinct from conventional generative models, our method does not necessitate the invertibility of the transformation map. Moreover, it circumvents the need for both mini-max optimization and the computation of the computationally intensive Jacobian determinant. One key component of our framework is the adaptively chosen family of test functions in the form of Gaussian kernel functions with centres selected from the generated data samples. Experimental results from several benchmark examples substantiate the efficacy of our method, which offers both low computational costs and excellent capability in exploring multiple meta-stable states.".

[56] **Onsager's Variational Principle: Theory and Applications**.

Tiezheng Qian. Hong Kong University of Science and Technology.

Abstract: In this talk, I will present a review of Onsager's variational principle (OVP), which is of fundamental importance to the linear irreversible thermodynamics. I will start from the Onsager-Machlup theory, which is based on the stochastic dynamics described by the overdamped Langevin equation. I will then focus on OVP and its applications. I will also briefly talk about the minimum action path for the most probable transition pathway in the study of rare events. Finally, some recent applications of OVP to the modelling of active soft matter will be presented.

[57] **Applications of the Onsager principle in numerical analysis**.

Xianmin XU. Chinese Academy of Sciences.

Abstract: The Onsager principle is a fundamental law for irreversible processes in statistic physics. It has been used to develop theoretical models for many problems in soft matter. Recently, the variational principle has been used as an approximation tool to derive reduced models for many complicated systems. In this talk,

we will present some applications the Onsager variational principle in numerical analysis, including derivation of a moving finite element method for gradient flows and geometric partial differential equations, etc.

[58] **Sharp interface limit and numerical methods for a ternary phase-field model**.

Zhen Zhang. Southern University of Science and Technology.

Abstract: In this talk, we undertake a study involving matched asymptotic analysis and numerical simulation of an algebraically consistent ternary phase-field model. By introducing only two completely independent phase-field functions and using a dichotomic representation, the model is derived from the energetic variational framework and consists of two highly coupled Cahn-Hilliard type equations with degenerate mobility. Using the method of matched asymptotic expansions, the Neumann angle condition, the dynamical laws for the interface and the triple junction are obtained at O(t) time scales. Moreover, based on the Strang splitting and stabilization technique, we propose a set of first- and second-order, decoupled, linear and energy stable temporal schemes for the model. We further prove that the developed schemes can guarantee the dissipation of the original energy, instead of the dissipation of modified energy. Additionally, we perform various numerical simulations to validate the theoretical derivation.

[59] **Parametric finite element methods for geometric flows**.

Chunmei Su. Tsinghua University.

Abstract: This talk includes two parts. (1) Firstly we present and analyze a semi-discrete parametric finite element scheme for solving the area-preserving curve shortening flow. The scheme is based on Dziuk's approach (SIAM J. Numer. Anal. 36(6): 1808-1830, 1999) for the anisotropic curve shortening flow. We prove that the scheme preserves two fundamental geometric structures of the flow with an initially convex curve: (i) the convexity-preserving property, and (ii) the perimeter-decreasing property. To the best of our knowledge, the convexity-preserving property of numerical schemes which approximate the flow is rigorously proved for the first time. Furthermore, the error estimate of the semi-discrete scheme is established, and numerical results are provided to demonstrate the structure-preserving properties as well as the accuracy of the scheme. (2) To avoid the clustering of nodes in the simulation of Dziuk's type schemes, we present some high-order methods based on the BGN formulation, which achieve high-order accuracy in time and exhibit good properties with respect to the mesh distribution.

[60] **Data and knowledge driven approaches for inverse problems in imaging**.

Wenbin Li. Harbin Institute of Technology Shenzhen.

Abstract: Using learning methods becomes a new trend in the solutions of inverse problems. End-to-end learning approaches are efficient, but the reliability of solutions and the generalization ability of networks are questionable. The data and knowledge driven approaches can alleviate these problems, and among them we focus on the method of data-driven regularization. The key idea is to construct a data-driven regularizer through neural networks and learning techniques, and employ the knowledge of the inversion model to capture the mathematical connection between the recovered solution and the measurement data. We will present two examples in this talk. (1) The iterated network Tikhonov (iNETT) method, where an iterated Tikhonov algorithm is developed by constructing a data-driven regularizer using uniformly convex neural networks. (2) The graphLaNet method, where the data-driven regularizer is built by the graph Laplacian upon a first approximation of the solution as the output of a trained neural network.

[61] **A Constrained Least-Squares Ghost Sample Points (CLS-GSP) Method for Differential Operators on Point Clouds**.

Kwunlun Chu. Hang Seng University of Hong Kong.

Abstract: We introduce a novel meshless method called the Constrained Least-Squares Ghost Sample Points (CLS-GSP) method for solving partial differential equations on irregular domains or manifolds represented by randomly generated sample points. Our approach involves two key innovations. Firstly, we locally reconstruct the underlying function using a linear combination of radial basis functions centered at a set of carefully chosen

ghost sample points that are independent of the point cloud samples. Secondly, unlike conventional least-squares methods, which minimize the sum of squared differences from all sample points, we regularize the local reconstruction by imposing a hard constraint to ensure that the least-squares approximation precisely passes through the center. This simple yet effective constraint significantly enhances the diagonal dominance and conditioning of the resulting differential matrix. We provide analytical evidence demonstrating that our method consistently estimates the exact Laplacian. Additionally, we presentvarious numerical examples showcasing the efficacy of our proposed approach in solving the Laplace/Poisson equation and related eigenvalue problems.

[62] **Band-times-Circulant preconditioners for non-symmetric Toeplitz systems**.

Grigorios Tachyridis. Hong Kong Baptist University.

Abstract: It is known that Toeplitz systems arise in a variety of applications, e.g., in economics, engineering, probabilities and many more. Such systems may also come up from the discretization of integro-differential equations, as well as of ordinary/partial/fractional differential equations. In this presentation we focus on the preconditioning of square and non-symmetric Toeplitz systems dealing with the well-conditioned case, using a specific circulant preconditioner, and also with the ill-conditioned one using a preconditioner arising from the combination of a band Toeplitz matrix and circulant matrices. For the solution of the system we use Krylov subspace methods and more precisely the Conjugate Gradient method for the corresponding preconditioned system of the normal equations (PCGN) and the Preconditioned Generalized Minimal Residual method (PGMRES). We show proven theoretical results, which guarantee the efficiency of the proposed preconditioning technique. Such efficiency is also shown by various numerical experiments given in the last part of the presentation.

[63] **A refinement of approximate invariant subspaces of matrices based on SVD in high dimensionality reduction and image compression**.

Peter Chang-Yi Weng. National Chiayi University.

Abstract: The techniques of high dimensionality reduction are important tools in machine learning and data science. The method of singular value decomposition (SVD) is a popular method in dimensionality reduction and image compression. However, it suffers from heavily computational overhead in practice, especially for images with high-resolution. In order to achieve the efficiency and the accuracy, we propose a refinement of approximate invariant subspaces of matrices (REIS) algorithm based on SVD. The theoretical contribution of our paper is threefold. Firstly, we describe the properties of the SVD of the matrices and discuss how to apply SVD to do image compression. Secondly, we introduce the method of REIS based on SVD for image compression in the high-resolution images. The core of REIS is adapted to large and real matrices in $R^(nn)$, through some nonsymmetric algebraic Riccati equations or their associated Sylvester equations via Newton's method. Thirdly, some measurement tools are provided such as compression ratio, mean square error, peak signal to noise ratio and structural similarity index to compare the performance of the compression factors and the quality of the compressed images. Numerical examples for testing some real world image sets are presented to illustrate the feasibility of our proposed algorithm.

[64] **Recent advances of integration preconditioning techniques of pseudospectral methods**.

Yung-Ta Li. Fu Jen Catholic University.

Abstract: "In this talk, we first introduce recent developments of integration preconditioners of pseudospectral methods that solve ordinary differential equation boundary value problems. The preconditioners are built on the analytical forms of the discrete inverse operators. Numerical examples are presented to validate the viability of the preconditioners. Moreover, we discuss the challenge of applying similar techniques for solving the 2D advection equations on the square.".

[65] **Exact Optimization: Application Spectrum**.

Li-Gang Lin. National Central University.

Abstract: Optimization is ubiquitous, and it is receiving more attention than ever. For example, it is central to data science, such as artificial intelligence. Although the mainstream literature resorts to numerical iterations for

an optimization task (commonly known as Numerical Optimization), the research path toward exact solutions has recently become clearer (namely Exact Optimization). Generally speaking, optimization problems can be categorized into three levels: the fundamental one is equality-constrained quadratic programming and the others are built upon it. In particular, Exact Optimization solves the fundamental problem analytically, algebraically, in derivative-free closed formulae, and without knowing a feasible point a priori and any time during the process. The practical impacts highlight its efficient realization on FPGA; in other words, the computational efficiency can be further enhanced using basic hardware platforms in terms of computing speed, accuracy, memory space, implementation cost, and overall size, simultaneously. Note that the state-of-the-art Exact Optimization only leverages elementary linear algebra to maximize its application coverage, which is still being pursued down the research path. This talk briefly summarizes the up-to-date theoretical findings and dominantly overviews the application spectrum of Exact Optimization. The focus sets on and responds to an intuitive question: Where to start the comparison study between the two methods?

[66] **Recent progress on numerical methods for quasiperiodic systems** .

Kai Jiang. Xiangtan University.

Abstract: Quasiperiodic systems, related to irrational numbers, are important space-filling structures without decay nor translational invariance. How to numerically compute these incommensurate systems poses challenges. In the past years, accurate and efficient methods of quasicrystals have been developed. In this talk, we will present recent progress on numerical methods for quasiperiodic systems, including periodic approximation method, projection method, and finite point recovery method. The corresponding approximation analysis will also be given. If time allows, we will present some applications, such as quasicrystals, grain boundaries, quasicrystal phase transition, quasiperiodic homogenization, quasiperiodic Schrodinger systems.

[67] **Optimization approach for dislocation structures and evolution** .

Shuyang Dai. Wuhan University.

Abstract: This study aims to enhance dislocation dynamics by incorporating the interacting energy of dislocation systems and proposing efficient methods to speed up simulations. By utilizing the nonsingular stress field theory for dislocations, the interacting energy is effectively managed within computationally feasible limits. The two-dimensional dislocation dynamics is reformulated as an optimization problem, which is solved using efficient techniques such as the energy splitting method and the nonlinear conjugate gradient method. Numerical experiments demonstrate that these optimization algorithms significantly reduce computation time compared to conventional methods such as the Runge-Kutta method.

[68] **Continuum Models for the Structure and Dynamics of Hetero-interfaces in Crystalline Materials** .

Luchan Zhang. Shenzhen University.

Abstract: The hetero-interfaces are commonly formed between different materials or different phases to accommodate the lattice misfit between the adjacent materials. Energetic and dynamic properties of hetero-interfaces strongly affects the mechanical, electronic and plasticity properties of the composite materials and alloys. These properties of hetero-interfaces strongly depend on their microscopic structures. We present continuum models for the energy and dynamics of hetero-interfaces based on the continuum distribution of the line defects-disconnections on them.

[69] **Unconditionally SO(3)-preserving and energy-stable rotational discrete gradient schemes for orthonormal frame gradient flow** .

Zhiguo Yang. Shanghai Jiao Tong University.

Abstract: We present a novel second-order rotational discrete gradient (Rdg) scheme for numerically approximating the orthonormal frame gradient flow of biaxial nematic liquid crystals. This scheme relies on reformulating the original gradient flow system into an equivalent generalised "rotational" form. A second-order discrete gradient approximation of the energy variation is then devised such that it satisfies an energy difference relation.

The proposed numerical scheme has two remarkable properties: (i) it strictly obeys the orthonormal property of the tensor field and (ii) it satisfies the energy dissipation law at the discrete level, regardless of the time step sizes. We provide ample numerical results to validate the accuracy, efficiency, unconditional stability and $SO(3)$-preserving property of this scheme. In addition, comparisons of the simulation results between the biaxial orthonormal frame gradient flow model and uniaxial Oseen-Frank gradient flow are made to demonstrate the ability of the former to characterize non-axisymmetric local anisotropy.

[70] **Mathematical Analysis of the Ensemble Kalman filter**.

Kota Takeda. Kyoto University.

Abstract: Data assimilation is a method of uncertainty quantification to estimate the hidden true state by updating the prediction owing to model dynamics with observation data. As a prediction model, I consider a class of chaotic dynamical systems including the Lorenz'63 and '96 equations. For nonlinear model dynamics, the ensemble Kalman filter (EnKF) is often used to approximate the mean and covariance of the probability distribution with a set of particles called an ensemble. In this talk, I consider a deterministic version of the EnKF known as the ensemble transform Kalman filter (ETKF), performing well even with limited ensemble sizes in comparison to other stochastic implementations of the EnKF. When the ETKF is applied to large-scale systems, an ad-hoc numerical technique called a multiplicative covariance inflation is often employed to reduce approximation errors. Despite the practical effectiveness of the ETKF, little is theoretically known. In this talk, I will present an error analysis of the ETKF with the multiplicative covariance inflation in an ideal setting.

[71] **Optimizing Strategy of Player Matching Queue of Online Games**.

Harumi Shuei. Waseda University Department of Science and Engineering.

Abstract: In this paper, we investigate the game Splatoon, a third-person shooter developed by Nintendo, where characters known as Inklings transform between humanoid and squid forms, aiming to cover the environment with their team's ink. Matchmaking is crucial for providing players with a positive gaming experience, ensuring balanced and competitive gameplay. Yet there are ongoing complaints about Splatoon's matchmaking system. Our study aims to analyze the current matchmaking system and propose optimizations to address these issues. We specifically focus on TrueSkill, a matchmaking system designed for multiplayer games that assesses and matches players based on their skill levels. Additionally, we classify players based on their game skills and model the queue for entering the game using a Markov Chain to determine the optimal thresholds for different skill levels. This approach allows us to balance the matchmaking process, ensuring that players are matched fairly while minimizing waiting times. Through our analysis, we discovered that for a model classifying players into high-level and low-level groups with skills formulated using a Uniform Distribution, the optimal threshold is $1/2$.

[72] **Riemannian conditional gradient methods for composite optimization problems**.

Kangming Chen. Kyoto University.

Abstract: This work introduces the Conditional Gradient method, commonly known as the Frank-Wolfe method, for composite problems on Riemannian manifolds. Building on existing research, we propose this method and provide an analysis of several types of line search step sizes, techniques for solving subproblems, and a detailed convergence analysis. Additionally, we discuss the implementation of the proposed algorithm for specific problems.

[73] **A Strong Second-Order Optimality Condition for Nonlinear Semidefinite Optimization**.

Huimin Li. Kyoto University.

Abstract: Recently, the approximate Karush–Kuhn–Tucker (AKKT) conditions, also called the sequential optimality conditions, have been proposed for Nonlinear Programming problems. These conditions are known as genuine necessary optimality conditions because all local optima satisfy them with no constraint qualification (CQ). In our study, we proposed a Strong Second-order Approximate KKT (SKKT2) condition for Nonlinear Semidefinite Programming problems, and showed it is a necessary condition for local minimizer.

[74] **Combinatorics of Phylogenetic Networks: Understanding Deviations from Tree-Based Networks**.

Takatora Suzuki. Waseda University.

Abstract: Phylogenetic networks are useful models that can represent reticulate evolution and complex biological data. In recent years, mathematical and computational aspects of 'tree-based' phylogenetic networks have been well studied. However, not all phylogenetic networks are tree-based, so it is meaningful to consider how close a given network is to being tree-based; Francis-Steel-Semple (2018) proposed several different indices to measure the degree of deviation of a phylogenetic network from being tree-based. Two of these deviation indices have been found to be efficiently computed in previous studies. However, the relationship between the above two is currently unknown, as they have been studied using different approaches. In this presentation, we derive tight inequalities for the values of the two indices and provide a characterisation of the phylogenetic network such that they coincide.

[75] **A Two Timescale Evolutionary Game Approach to Multi-Agent Learning and its Application in Algorithmic Collusion Study**.

Nan Chen. The Chinese University of Hong Kong.

Abstract: We propose a two-time scale evolutionary game approach to solving multi-agent reinforce- ment learning (MARL) problems. Three key components underly the algorithm design. First, we use the perturbed best response to update agents' belief. Second, we use the fictitious play rule to update the agents' beliefs about their opponents. Third, policies and beliefs are updated at different learning rates from those used for Q-value updating. The new approach provably converges to epsilon-Nash equilibria of general-sum MARL problems without imposing restrictive assumptions that are typically needed in the literature. AI-powered algorithms are now widely adopted in marketplaces to price goods and services. However, serious concerns have been raised by the regulators and academics about the possibility that these algorithms may learn to collude through their strategic interactions. Researchers predominately use Q-learning to model the behavior of pricing algorithms, which lacks of convergence guarantees in multi-agent setup. Our approach provides an innovative framework for algorithmic collusion studies. Numerical experiments demon- strate how agents can learn collusive pricing policies and, more importantly, a punishment strategy to sustain collusion.

[76] **TD learning for high-dimensional PIDEs with jumps**.

Yi Zhu. Tsinghua University.

Abstract: In this talk, I will introduce a deep learning framework, which we proposed recently, for solving high-dimensional partial integro-differential equations (PIDEs) based on the temporal difference learning. We introduce a set of Levy processes and construct a corresponding reinforcement learning model. To simulate the entire process, we use deep neural networks to represent the solutions and non-local terms of the equations. Subsequently, we train the networks using the temporal difference error, termination condition, and properties of the non-local terms as the loss function. Our method demonstrates the advantages of low computational cost and robustness, making it well-suited for addressing problems with different forms and intensities of jumps. At the end I shall introduce how to apply our method to multi-agent relative Investment games in a jump diffusion market.

[77] **Generalized Moving Least-Squares Methods for Solving Scalar- and Vector-Valued PDEs on Manifolds**.

Shixiao Jiang. ShanghaiTech University.

Abstract: In this talk, we review generalized moving least-squares (GMLS) approach, and discuss its applications in solving scalar- and vector-valued PDEs on unknown compact Riemannian submanifolds of the Euclidean domain, identified by randomly sampled data that (almost surely) lie on te interior of the manifolds. For scalar-valued PDEs, we illustrate the approach by approximating the Laplace-Beltrami operator, where a stable approximation is achieved by either GMLS using appropriated weighted norms or a combination of GMLS and a novel linear programming that relaxes the diagonal-dominant constraint for the estimator. For the Dirichlet Poisson problem where no data points on the boundaries are available, we employ GMLS with

the volume-constraint approach that imposes the boundary conditions on data points close to the boundary. We establish the theoretical convergence in solving Poisson PDEs and numerically demonstrate the accuracy on simple smooth manifolds of low and moderate high co-dimensions as well as unknown 2D surfaces. Last, we will discuss our recent progress on solving vector-valued PDEs on submanifolds of the Euclidean domain.

[78] **Deep adaptive sampling for surrogate modeling without labeled data**.

Kejun Tang. TBD.

Abstract: Surrogate modeling is of great practical significance for parametric differential equation systems. In contrast to classical numerical methods, using physics-informed deep learning methods to construct simulators for such systems is a promising direction due to its potential to handle high dimensionality, which requires minimizing a loss over a training set of random samples. However, the random samples introduce statistical errors, which may become the dominant errors for the approximation of low-regularity and high-dimensional problems. In this work, we present a deep adaptive sampling method for surrogate modeling of low-regularity parametric differential equations and illustrate that this mechanism is necessary for constructing surrogate models. In the parametric setting, the residual loss function can be regarded as an unnormalized probability density function (PDF) of the spatial and parametric variables. This PDF is approximated by a deep generative model, from which new samples are generated and added to the training set. Since the new samples match the residual-induced distribution, the refined training set can further significantly reduce the statistical error in the current approximate solution. We demonstrate the effectiveness of the proposed method with a series of numerical experiments, including the physics-informed operator learning problem, the parametric optimal control problem with geometrical parametrization, and the parametric lid-driven 2D cavity flow problem with a continuous range of Reynolds numbers from 100 to 1000.

[79] **A neural multigrid solver for Helmholtz equations with high wavenumber and heterogeneous media**.

Chen Cui. Xiangtan university.

Abstract: In this report, we will present a neural multigrid (MG) solver for Helmholtz equations with high wavenumbers and heterogeneous media. Through spectral analysis of conventional MG methods applied to the Helmholtz equation, we partition the iteration error into characteristic and non-characteristic components. Non-characteristic components are effectively mitigated using a standard MG V-cycle, the so-called wave cycle, which incorporates carefully chosen smoothers at each level. Characteristic components are addressed through solving an advection-diffusion-reaction (ADR) equation utilizing another MG V-cycle at a coarser scale, termed the ADR cycle. The resulting solver, termed Wave-ADR, enables the handling of error components with varying frequencies and overcoms constraints on the number of grid points per wavelength at coarse grids. Furthermore, we give an efficient implementation leveraging differentiable programming, thereby making Wave-ADR able to function as an end-to-end Helmholtz solver, incorporating parameters learned in an unsupervised manner. Numerical experiments demonstrate that Wave-ADR efficiently solves heterogeneous 2D Helmholtz equations with wavenumber exceding 2000. Comparative experiments against classical MG preconditioners and existing deep learning-enhanced MG preconditioners show the superior efficacy of Wave-ADR.

[80] **Deeper or Wider: A Perspective from Optimal Generalization Error with Sobolev Loss**.

Yahong Yang. The Pennsylvania State University.

Abstract: Constructing the architecture of a neural network is a challenging pursuit for the machine learning community, and the dilemma of whether to go deeper or wider remains a persistent question. This paper explores a comparison between deeper neural networks (DeNNs) with a flexible number of layers and wider neural networks (WeNNs) with limited hidden layers, focusing on their optimal generalization error in Sobolev losses. Analytical investigations reveal that the architecture of a neural network can be significantly influenced by various factors, including the number of sample points, parameters within the neural networks, and the regularity of the loss function. Specifically, a higher number of parameters tends to favor WeNNs, while an increased number of sample points and greater regularity in the loss function lean towards the adoption of DeNNs. We ultimately apply this

theory to address partial differential equations using deep Ritz and physics-informed neural network (PINN) methods, guiding the design of neural networks.

[81] **Optimization and preconditioning: TPD algorithms for nonlinear PDEs**.

Ruchi Guo. The Chinese University of Hong Kong.

Abstract: "Abstract: In physics and mathematics, a large class of PDE systems can be formulated as minimizing energy functionals subject to certain constraints. Lagrange multipliers are widely used for solving these problems, which however leads to minmax optimization problems, i.e., saddle point systems. The development of fast solvers for saddle point systems, especially the nonlinear ones, is particularly difficult in the sense that (i) one has to consider the preconditioning in two directions and (ii) the preconditioners have to evolve in iteration due to the nonlinearity. In this work, we introduce an efficient transformed primal-dual (TPD) algorithm to solve the aforementioned nonlinear saddle point problems. We prove the optimal convergence in terms of the condition number. We apply the algorithm to a nonlinear Maxwell equation and show that it is much more efficient than some traditional fixed point and projected gradient descent algorithms.".

[82] **Real-time simulation of open spin models with tensor operations**.

Geshuo Wang. National University of Singapore.

Abstract: We study the real-time simulation of open quantum systems, where the system is modeled by a diagram that represents the connection between spins, with each spin associated with its own harmonic bath. Our method first decoupled the system to be a single spin problem and the inchworm method is applied for the single spin problem. By designing proper data structure, the quantities on single spin can be formally considered as a tensor. Connecting single spins to the full diagram therefore becomes tensor operators. Numerical test will be carried out in some simple examples to validate our method.

[83] **R Package CFO: Calibration-Free Odds Designs for Dose-Finding Clinical Trials**.

Guosheng Yin. The University of Hong Kong.

Abstract: The implementation of machine learning (ML) methods in phase I clinical trials remains a relatively unexplored area. The calibration-free odds type (CFO-type) of designs, as data-driven decision-making Bayesian approaches, leverage historical cumulative data across various dose levels, primarily aiming at identifying the maximum tolerated dose (MTD). Inheriting the ideas from game theory or tug-of-war, CFO mimics the games of force: one pushes the dose down while the other pushes it up. Extensive simulations validate that CFO-type designs maintain an optimal balance between efficiency and safety in MTD identification, with performance metrics that are comparable to, or occasionally surpass the state-of-the-art methods. This article introduces the R package CFO for implementing and assessing CFO-type designs in phase I clinical trials. In addition to the fundamental CFO design, the CFO package encompasses various variants tailored to accommodate different scenarios. These include the two-dimensional CFO (2dCFO) designed for drug-combination trials, accumulative CFO (aCFO) for accruing all dose information, time-to-event CFO (TITE-CFO), and fractional CFO (fCFO) which are developed to specifically address late-onset toxicity. Moreover, hybrid designs such as TITE-aCFO and f-aCFO, which integrate both late-onset toxicity and all dose information for decision making, are also included. CFO provides a robust set of functions used for determining subsequent cohort doses, selecting the MTD, and conducting simulations to evaluate design operating characteristics. The properties and results are presented to trial investigators through simple textual and graphical outputs. The user-friendly interface, adaptability to various design considerations, and the comprehensive implementation of CFO-type designs position CFO as a noteworthy machine learning tool for phase I clinical trials.

[84] **Mars landing parachute simulation with AERO-Suite**.

Zhengyu Huang. Peking University.

Abstract: A high fidelity multi-physics Eulerian computational framework is presented for the simulation of supersonic parachute inflation for landing on Mars. Several adaptive mesh refinement (AMR)-enabled, large edge simulation (LES)-based simulations of the full-size disk-gap-band (DGB) parachute inflating in the low-density

low-pressure Martian atmosphere are reported. The comparison of the drag histories and the first peak forces between the simulation results and experimental data collected during NASA Curiosity Rover's Mars atmospheric entry shows reasonable agreements. This framework demonstrates the potential of using Computational Fluid Dynamics (CFD) and Fluid-Structure Interaction (FSI) based simulation tools for the future supersonic parachute design.

[85] **TSEMLib: a tetrahedral spectral element method based C++ library for high-order numerical solutions of PDEs**.

Hongfei Zhan. Peking University.

Abstract: In this work, a novel open-source general-purpose C++ library TSEMLib, developed for high order numerical methods for PDEs, is introduced. The design philosophy of the library, tetrehedral spectral element method used for discretizing partial differential equations, numerical algorithm for efficient solving the linear system, as well as the post-processing of simulations such as visualizations are described systematically for our package. Numerical simulations of model problems showcase the capability of the library as both a TSEM package and a high-order approach. Moreover, an application to all-electron Kohn-Sham model is presented, exhibiting the potential of our package to electronic structure calculations. Additionally, due to efficiency concern, the integration with AFEPack on r-adaptivity is demonstrated. All these examples fully exhibit the ability and potential of our package to scientific inquiries and engineering endeavors. The future works on developing the library are also discussed.

[86] **Optimal Mass Transport Mappings with Application to Brain Tumor Segmentation**.

Mei-Heng Yueh. National Taiwan Normal University.

Abstract: The optimal mass transport (OMT) aims to find a measure-preserving mapping that minimizes a given cost functional. The OMT mapping has been widely applied to various tasks in computer vision and graphics. Based on our developed theoretical frameworks on nonlinear energy minimization and associated efficient numerical algorithms for measure-preserving mappings, the OMT mapping can be effectively computed. In this talk, I will introduce the theoretical frameworks used for computing OMT mappings and demonstrate their practical applications in manifold registration and 3D image processing for brain tumor segmentation.

[87] **OPTIMAL REPLENISHMENT POLICY FOR A DETERIORATED INVENTORY MODEL WITH TIME-AND STOCK-DEPENDENT DEMAND**.

Dharma Lesmono. Universitas Katolik Parahyangan.

Abstract: In this paper, we consider a mathematical model for deteriorated items, where demands are time- and stock-dependent. The decision variables in the model are the time between replenishment and the time when the stock drops to zero. We consider three items, and the optimal replenishment policy is determined among the possible replenishment policies, namely individual replenishment policy, joint replenishment policy and semi-joint replenishment policy.

[88] **Analysis of an energy-dissipating finite volume scheme on admissible mesh for the aggregation-diffusion equations**.

Ping Zeng. University of Electronic Science and Technology of China Institute of Fundamental and Frontier Sciences.

Abstract: We develop the numerical analysis of an energy-dissipating finite volume scheme on admissible meshes for the non-local, nonlinear aggregation-diffusion equations. Crucially, this scheme keeps the dissipation property unconditionally of an associated fully discrete energy and preserves the mass and positivity conservation of the density. We establish the well-posedness, stability, and error analysis of the method. Several numerical examples are presented to verify the theoretical results.

[89] **The well-posedness and discontinuous Galerkin approximation for the Non-Newtonian Stokes–Darcy–Forchheimer coupling system**.

Jingyan Hu. The University of Electronic Science and Technology of China.

Abstract: We study the non-Newtonian Stokes–Darcy–Forchheimer system modeling the free fluid coupled with the porous medium flow with shear/velocity-dependent viscosities. The unique existence is proved by using the theory of nonlinear monotone operator and a coupled inf-sup condition. Moreover, we apply the discontinuous Galerkin (DG) method with P^k/P^{k-1}-DG element for numerical discretization and obtain the well-posedness, stability, and error estimate. For both the continuous and the discrete problem, we explore the convergence of the Picard iteration (or called Kacǎnov method). The theoretical results are confirmed by the numerical examples.

[90] **Direct self-gravitational force calculation of infinitesimally thin gaseous disks based on adaptive mesh refinement accelerated by the fast Fourier transform**.

Chien-Chang Yen. Fu Jen Catholic University.

Abstract: The central region of galaxies can be an infinitesimally thin gaseous disk due to the angular moment conservation. Dynamic of gaseous disks is significant for probing the gas flows inward/outward to the origin of galaxies. Moreover, self-gravitational force calculation should be concerned during the evolution of galaxies. The numerical calculation of force of second order has been represented by the con- volution of the Green function and surface density. It is known that the calculation of a convolution of two vectors can be speed up by fast Fourier transform (FFT) from the numerical complexity $O(N^2)$ to $O(N \log N)$, where N is the total number of zones. The apative mesh refinement (AMR) is adopted if some particular region is interest in high resolution. On the other hand, the AMR approach may induce a problem of fast computation whenever employing FFT into the calculation. Fortunately, we can use the fast Fourier transform (sFFT) to preserve the nearly linear complexity $O(N \log N)$ for numerical calculation based on AMR in this presentation.

[91] **Dynamics of Heteroclinic Networks: Unraveling Complex Interactions and Stability**.

Darlington S. David. University of Liberia.

Abstract: This research delves into the intricate realm of dynamical systems theory, focusing on the "Dynamics of Heteroclinic Networks" to unravel the complexities inherent in their formation, evolution, and stability. Heteroclinic networks, characterized by connected trajectories approaching distinct equilibrium points, are pervasive in various scientific and engineering domains. The primary objectives of this study include characterizing their formation and stability, exploring the influence of network topology, and investigating their role in triggering transitions between dynamic regimes. Employing a combination of mathematical modeling, numerical simulations, network theory, and bifurcation analysis, this research aims to provide a comprehensive understanding of heteroclinic networks. The outcomes are expected to contribute to fundamental principles, offer insights into network topology's impact, and identify practical applications across diverse fields, from neuroscience to engineering. Through theoretical advancements and practical implications, this research seeks to shed light on the dynamics of complex interactions, paving the way for innovative applications and control strategies in real-world systems.

[92] **The mixed method with two Lagrange multiplier formulations for the Signorini problem**.

Qi Wang. University of Electronic Science and Technology of China.

Abstract: Introducing stress as a new unknown, we consider the Signorini problem in the mixed form. The well-posedness theory of the continuous and discrete mixed variational inequalities has been established by reformulating them into projection problems. Two Lagrange multiplier formulations are introduced utilizing different projections. The equivalency among the Lagrange multiplier formulations and the mixed variational inequality is demonstrated in continuous and discrete sense, respectively. For the discrete mixed variational inequality, we develop the error estimates. Based on two Lagrange multiplier formulations, we design two Active/Inactive set algorithms and investigate the convergence. Several numerical experiments are conducted to verify the theoretical convergence rates of the finite element discretization and the iteration algorithms.

[93] **Splitting-based numerical algorithm for reaction-diffusion systems**.

Sungha Yoon. Ewha Womans University.

Abstract: We present a splitting-based hybrid numerical scheme for reaction-diffusion systems, especially focusing on the second-order parabolic. Pre-computing process and interpolating functions are adopted, and we

can assure the boundedness of nonlinear terms at each step of time integration. The stability and convergence of the scheme has been discussed, and we perform numerical simulations to verify the agreements between the theoretical and numerical results.

[94] **Unveiling Community Structures: The Role of Modularity in Network Analysis, with Insights from China's Migration Patterns**.

Fatimah Abdul Razak. Universiti Kebangsaan Malaysia.

Abstract: Modularity is a metric in network science used to evaluate the quality of a network's division into communities by comparing the density of links within communities to the density of links between them. A high modularity value indicates a strong community structure, with nodes within the same community more densely connected to each other than to nodes in different communities. This measure is crucial for community detection algorithms like the Louvain method, which aim to maximize modularity to find optimal network partitions. In our analysis of China's migration network, applying the Louvain algorithm revealed distinct regional communities that reflect the spatial distribution of provinces, highlighting the significant influence of regional proximities on migration patterns.

[95] **A structure-preserving parametric finite element method for geometric PDEs and applications**.

Weizhu Bao. National University of Singapore.

Abstract: In this talk, I begin with a review of different geometric flows (PDEs) including mean curvature (curve shortening) flow, surface diffusion flow, Willmore flow, etc., which arise from materials science, interface dynamics in multi-phase flows, biology membrane, computer graphics, geometry, etc. Different mathematical formulations and numerical methods for mean curvature flow are then discussed. In particular, an energy-stable linearly implicit parametric finite element method (PFEM) is presented in details. Then the PFEM is extended to surface diffusion flow and anisotropic surface diffusion flow, and a structure-preserving implicit PFEM is proposed. Finally, sharp interface models and their PFEM approximations are presented for solid-state dewetting. This talk is based on joint works with Harald Garcke, Wei Jiang, Yifei Li, Robert Nuernberg, Yan Wang and Quan Zhao.

[96] **New artificial tangential motions for parametric finite element approximation of surface evolution**.

Buyang Li. Hong Kong Polytechnic University.

Abstract: New parametric finite element methods, with new types of artificial tangential velocity constructed at the continuous level, are introduced for solving surface evolution under external velocity fields or geometric flows, in comparison with other available methods such as the parametric finite element methods proposed by Barrett, Garcke & Nürnberg in 2008, and the DeTurck flow techniques proposed by Elliott & Fritz in 2017.

[97] **A structure-preserving parametric finite element method for geometric flows with anisotropic surface energy**.

Yifei Li. National University of Singapore.

Abstract: Designing a numerical scheme that can preserve the geometric structure for anisotropic surface diffusion with an arbitrary anisotropic surface energy is a long-standing problem. In this talk, we propose and analyze a structure-preserving parametric finite element methods (SP-PFEM) for the evolution of a closed curve in 2D, which preserve two geometric structures – area conservation and energy dissipation – at the full-discretized level, The SP-PFEM innovates with a novel surface energy matrix and the Cahn-Hoffman ξ-vector, leading to a new geometric identity for dealing with the weighted mean curvature. This new identity allows our SP-PFEM to be easily extended to various geometric flows with anisotropic effects. Extensive numerical results demonstrate its efficiency, stability, and success in other geometric flows.

[98] **A variational front-tracking method for multiphase flow**.

Quan Zhao. University of Science and Technology of China.

Abstract: In this talk I will introduce a variational front-tracking approximation for the multiphase flow. The fluid interfaces are represented by curve networks in 2d or surface clusters in 3d with possible triple junctions where three interfaces meet and boundary lines where an interface meet an fixed planer boundary. I will first present a linear method with an unconditional stability estimate, where the existence and uniqueness of solution can be shown. We next adapt the introduced method to achieve an exact volume preservation for the discrete solutions.

[99] **A novel fourth-order scheme for two-dimensional Riesz space fractional nonlinear reaction-diffusion equations and its optimal preconditioned solver**.

Yuanyuan Huang. Hong Kong Baptist University.

Abstract: A novel fourth-order finite difference formula coupling the Crank-Nicolson explicit linearized method is proposed to solve Riesz space fractional nonlinear reaction-diffusion equations in two dimensions. Theoretically, under the Lipschitz assumption on the nonlinear term, the proposed high-order scheme is proved to be unconditionally stable and convergent in the discrete L^2-norm. Moreover, a τ-matrix based preconditioner is developed to speed up the convergence of the conjugate gradient method with an optimal convergence rate (a convergence rate independent of mesh sizes) for solving the symmetric discrete linear system. Theoretical analysis shows that the spectra of the preconditioned matrices are uniformly bounded in the open interval (3/8, 2). To the best of our knowledge, this is the first attempt to develop a preconditioned iterative solver with a mesh-independent convergence rate for the linearized high-order scheme. Numerical examples are given to validate the accuracy of the scheme and the effectiveness of the proposed preconditioned solver.

[100] **A convergence analysis based on the multi-mesh adaptive finite element method for Kohn-Sham models in all-electron calculations**.

Yedan Shen. Guangdong University of Technology.

Abstract: "A novel solver for the Kohn–Sham equation by employing the multi-mesh adaptive technique has been proposed to reduce the computational cost, in which the Kohn–Sham equation and the Poisson equation are solved in two different meshes on the same computational domain, respectively. A number of numerical experiments have been delivered to show the convergence and efficiency of the multi-mesh h-adaptive method. However, there is still lacking the theoretical convergent results. In this work, a theoretical convergence analysis has been given to explain the convergence behavior of the numerical methods, which provides a solid foundation for the multi-mesh h-adaptive method in the all-electron calculation.".

[101] **NURBS-Enhanced Finite Element Method for the Phonon Boltzmann Transport Equation**.

Dingtao Shen. The Hong Kong University of Science and Technology.

Abstract: "The multiscale nature of phonon transport presents significant modeling challenges. In the regime where the classical Fourier's law is no longer valid, the phonon Boltzmann transport equation (BTE) often plays a significant role. Nevertheless, direct numerical simulation of BTE suffers high computational cost due to the high dimensionality, where the independent variables include the time, spatial coordinates, and phonon angular and dispersion properties. Therefore, high-order discretization methods are necessary to reduce the degrees of freedom in the discrete system. The high-order discontinuous Galerkin (DG) finite element method for solving BTE has been developed by the authors on general triangular meshes. Compared to other discretization techniques, such as the finite volume method, this method can achieve the same order of accuracy on a spatial grid with much fewer elements. However, when complex geometries are present in the domain, e.g., porous graphene using for efficient heat dissipation, a piece-wise linear approximation to the boundary can reduce the convergence rate of the DG method. The NURBS (Non-Uniform Rational B-Spline) -Enhanced Finite Element Method (NEFEM) has been proposed to offer an efficient way for accurately describing arbitrary geometries, since the exact representation of curved boundaries given by NURBS enables the domain to be meshed independently of its geometric complexity. In this work, the NEFEM is incorporated into the DG solver for the phonon BTE, and the NURBS-Enhanced elements are adopted in meshes to model the curved physical boundary. The proposed method is capable of completely eliminating the uncertainties introduced by the de-featuring and piecewise linear approximation to a complex geometry in any classical numerical method and, thus, can significantly reduce the necessary number of

degrees of freedom to achieve the desired accuracy. A comparison of the NEFEM with the classical isoparametric FEM over BTE is presented by numerical experiments, demonstrating its superiority in obtaining an accurate solution on a coarse mesh and high-order interpolation.”.

[102] **Robust PDE Identification from a Noisy Data Set**.

Hao Liu. Hong Kong Baptist University.

Abstract: Partial differential equation (PDE) is an important tool to describe physical laws in many disciplines. Usually PDEs are derived from empirical observations. As the advances of technology, large amounts of data are easy to collect and store, which provides new opportunities for data-driven identification of PDE. This presentation addresses our recent work on identifying parametric and nonlocal PDEs. In PDE identification, many existing methods cannot deal with data with heavy noise. We propose a successively denoised differentiation strategy to denoise the data and compute partial derivatives with improved accuracy. We propose two methods to identify parametric PDEs. Our methods are based on the subspace pursuit algorithm, cross validation error and multi-shooting time evolution error, and can efficiently identify the underlying PDE from data with large noise. For nonlocal PDEs, we propose a model and a split Bregman algorithm to identify the underlying potential of the aggregation equation from a noisy data set. We also extend our algorithm to identify time-varying potentials, as well as to identify the interaction kernel in an agent-based system.

[103] **Normalized DNN for ground states of BEC**.

Xiaofei Zhao. Wuhan University.

Abstract: The talk is to consider the ground state solution of Bose-Einstein condensates (BEC) by using the deep neural network approach. We first reivew the classical methods and the existing AI methods for the model. Then, a normalized deep neural network is introduced to meet the mass constraint, which turns the constraint minization problem in functional space into a unconstraint minization in parametric space. The approximations of the ground state and also the first excited state can be obtained effectively in a unsupersived learning manner.

[104] **Structure and Gradient Flow Near Global Minima of Two-layer Neural Networks** .

Tao Luo. Shanghai Jiao Tong University.

Abstract: Under mild assumptions, we investigate the structure of loss landscape of two-layer neural networks near global minima, determine the set of parameters which recovers the target function, and characterize the gradient flows around it. With novel techniques, our work uncovers some simple aspects of the complicated loss landscape and reveals how model, target function, samples and initialization affect the training dynamics differently. These results concludes that two-layer neural networks can be recovered locally at overparameterization.

[105] **Universality of Condensation in Neural Networks Trained by Various Algorithms** .

Yuqing Li. Shanghai Jiao Tong University.

Abstract: The phenomenon of distinct behaviors exhibited by neural networks under varying scales of initialization remains an enigma in deep learning research. In this talk, we firstly present a phase diagram of initial condensation for two-layer neural networks. Condensation is a phenomenon wherein the weight vectors of neural networks concentrate on isolated orientations during the training process, and it is a feature in non-linear learning process that enables neural networks to possess better generalization abilities. Secondly, we focus on the investigation of convolutional neural networks (CNNs). Our experiments suggest that when subjected to small initialization and gradient-based training methods, kernel weights within the same CNN layer also cluster together during training, demonstrating a significant degree of condensation. These two works combined represents a step towards a better understanding of the non-linear training behavior exhibited by neural networks. Finally, we remark that Dropout is a widely utilized regularization technique in the training of neural networks, nevertheless, its underlying mechanism and its impact on achieving good generalization abilities remain poorly understood. We derive the stochastic modified equations for analyzing the dynamics of dropout, where its discrete iteration process is approximated by a class of stochastic differential equations. This theoretical finding make a substantial contribution to our understanding of the inherent tendency of Dropout to faciliate condensation.

[106] **Dynamics of initial condensation in neural networks** .

Zheng-An Chen. Shanghai Jiao Tong University.

Abstract: In this talk, we will explain the mechanism of initial condensation phenomena in neural networks from a dynamical perspective. Condensation refers to the tendency of neural network parameters to align along certain orientations during training, a process that simplifies the model's complexity and enhances generalization capabilities. Starting with a two-layer neural network model, we will demonstrate the emergence of initial condensation by approximating the gradient descent dynamics with effective dynamics, supported by rigorous error estimate. For the more complex three-layer neural networks, we will show of a blow-up property in the effective dynamics and provide a sufficient condition for condensation to occur. These theoretical insights are verified by empirical evidence.

[107] **Uniform Regularity for Incompressible MHD Equations in a Bounded Domain with Curved Boundary in 3D**.

Yingzhi Du. City University of Hong Kong.

Abstract: For the initial boundary problem of the incompressible MHD equations in a bounded domain with general curved boundary in 3D with the general Navier-slip boundary conditions for the velocity field and the perfect conducting condition for the magnetic field, we establish the uniform regularity of conormal Sobolev norms and Lipschitz norms to address the anisotropic regularity of tangential and normal directions, which enable us to prove the vanishing dissipation limit as the viscosity and the magnetic diffusion coefficients tend to be zero. We overcome the difficulties caused by the intricate interaction of boundary curvature, velocity field, and magnetic fields and resolve the issue caused by the problem of the viscosity and magnetic diffusion coefficients are not required to be equal.

[108] **SignReLU neural network and its approximation ability**.

Jianfei Li. City University of Hong Kong.

Abstract: Deep neural networks (DNNs) have garnered significant attention in various fields of science and technology in recent years. Activation functions define how neurons in DNNs process incoming signals for them. They are essential for learning non-linear transformations and for performing diverse computations among successive neuron layers. In the last few years, researchers have investigated the approximation ability of DNNs to explain their power and success. In this paper, we explore the approximation ability of DNNs using a different activation function, called SignReLU. Our theoretical results demonstrate that SignReLU networks outperform rational and ReLU networks in terms of approximation performance. Numerical experiments are conducted comparing SignReLU with the existing activations such as ReLU, Leaky ReLU, and ELU, which illustrate the competitive practical performance of SignReLU.

[109] **Double hump in a 5-neighbor cellular automaton**.

Kazuya Okamoto. Waseda University.

Abstract: One-dimensional neighborhood-three cellular automata are called elementary cellular automata (ECA), and among them, a model called ECA184 is well known as a mathematical model to represent traffic flow. In recent years, there has been much research on one-dimensional neighborhood-five cellular automata. In this study, we show that one of the one-dimensional neighborhood-five cellular automata is a suitable model for representing pedestrian flow since it expresses a property called double hump of the fundamental diagram obtained from pedestrian flow. We also introduce a fuzzified model of that cellular automaton.

[110] **Landau damping for the high dimensional two-species Vlasov-Poisson system**.

Zhiwen Zhang. The Chinese University of Hong Kong.

Abstract: This seminar investigates Landau damping in the context of the two-species Vlasov-Poisson system, with a specific focus on Penrose stable equilibria on the torus $\mathbb{T}^d \times \mathbb{R}^d$. Building upon the foundational work of Mouhot and Villani, we extend their analysis to the two-species variant of the Vlasov-Poisson system. Our approach employs a precise resolvent estimate to establish the occurrence of linear Landau damping. Additionally, we utilize a rigorous bootstrap analysis to confirm the presence of nonlinear Landau damping within the system.

[111] **An iterative constraint energy minimizing generalized multiscale finite element method for contact problem**.

Zishang Li. The Chinese University of Hong Kong.

Abstract: This work presents an Iterative Constraint Energy Minimizing Generalized Multiscale Finite Element Method for solving the contact problem with high contrast coefficients. The model problem can be characterized by a variational inequality, where we add a penalty term to convert this problem into a non-smooth and non-linear unconstrained minimizing problem. The characterization of the minimizer satisfies the variational form of a mixed Dirilect-Neumann-Robin boundary value problem. So we apply CEM-GMsFEM iteratively and introduce special boundary correctors along with multiscale spaces to achieve an optimal convergence rate. Numerical results are conducted for different highly heterogeneous permeability fields, validating the fast convergence of the CEM-GMsFEM iteration in handling the contact boundary and illustrating the stability of the proposed method with different sets of parameters. We also prove the fast convergence of the proposed iterative CEM-GMsFEM method and provide an error estimate of the multiscale solution under a mild assumption.

[112] **Algorithms for Topology Optimization Based on Bi-level Models and Variational Inequalities**.

Yixuan Zhang. The Hong Kong Polytechnic University.

Abstract: Topology optimization is widely applied in industrial problems but has limited analysis from the perspective of mathematical programs. In this work, we model the topology optimization problem to be a bi-level optimization problem, including a Variational Inequality (VI) problem as the constraint. In dealing with the nonsmoothness coming from the projection operator to solve the VI, we use the smoothing method, which brings about the differentiability of the smoothed problem. After that we introduce an auxiliary variable and design the algorithm based on the implicit function theorem. We prove that the algorithm would converge to the KKT point of the original problem along with the shrinkage of smoothing parameter, with the help of Lyapunov function. Numerical experiments are conducted to verify the convergence of our algorithm.

[113] **Error estimates of numerical methods for the nonlinear Schrödinger equation with low regularity potential and nonlinearity**.

Chushan Wang. National University of Singapore.

Abstract: We establish error estimates of various numerical methods for the nonlinear Schr"odinger equation (NLSE) with low regularity potential and nonlinearity covering purely bounded potential and local Lipschitz nonlinearity. Typical examples include the discontinuous or disorder potential and the non-integer power nonlinearity. New analysis techniques are needed to establish error bounds on classical numerical methods for low regularity potential and nonlinearity. Also, novel accurate, efficient and structure-preserving numerical methods for low regularity potential and nonlinearity need to be developed.

[114] **Non-convergence Analysis of Probabilistic Direct Search**.

Cunxin Huang. The Hong Kong Polytechnic University.

Abstract: Direct search is a popular method in derivative-free optimization. Probabilistic direct search has attracted increasing attention in recent years due to both its practical success and theoretical appeal. It is proved to converge under certain conditions at the same global rate as its deterministic counterpart, but the cost per iteration is much lower, leading to significant advantages in practice. However, a fundamental question has been lacking a systematic theoretical investigation: when will probabilistic direct search fail to converge? We answer this question by establishing the non-convergence theory of probabilistic direct search. We prove that probabilistic direct search fails to converge if the searching set is probabilistic ascent. Our theory not only deepens our understanding of the behavior of the algorithm, but also clarifies the limit of reducing the cost per iteration by randomization, and hence provides guidance for practical implementations of probabilistic direct search.

[115] **PF-ABGen: A Reliable and Efficient Antibody Generator via Poisson Flow**.

Chutian Huang. Hong Kong University of Science and Technology.

Abstract: An antibody is a special type of protein in the immune system to recognize and neutralize pathogenic targets, including bacteria and viruses. Antibody design is therefore valuable for the development of new therapeutics, while experimental- based methods are generally inefficient and expensive. Despite the fruitful progress in protein design with generative neural networks, including diffusion models, they still suffer from high computational costs. In this work, we propose Poisson Flow based AntiBody Generator (PF-ABGen), a novel antibody structure and sequence designer. We adopt the protein structure representation with torsion and bond angles, which allows us to represent the conformations more elegantly, and take advantage of the efficient sampling procedure of the Poisson Flow Generative Model. Our computational experiments demonstrate that PF-ABGen can generate natural and realistic antibodies in an efficient and reliable way. Notably, PF-ABGen can also be applied to antibody design with variable lengths.

[116] **High order in time, BGN-based parametric finite element methods for solving geometric flows**.

Wei Jiang. Wuhan University.

Abstract: Geometric flows have recently attracted lots of attention from scientific computing communities. One of the most popular schemes for solving geometric flows is the so-called BGN scheme, which was proposed by Barrett, Garcke, and Nurnberg (J. Comput. Phys., 222 (2007), pp. 441–467). However, the BGN scheme only can attain first-order accuracy in time, and how to design a temporal high-order numerical scheme is challenging. Recently, based on a novel approach, we have successfully proposed temporal high-order, BGN-based parametric finite element method for solving geometric flows of curves/surfaces. Furthermore, we point out that the shape metrics (i.e., manifold distance), instead of the function norms, should be used to measure numerical errors of the proposed schemes. Finally, ample numerical experiments demonstrate that the proposed BGN-based schemes are high-order in time in terms of the shape metric, and much more efficient than the classical BGN schemes.

[117] **Decoupled and energy stable schemes for a phase-field surfactant model based on a operator splitting technique**.

Nan Lu. Southern University of Science and Technology.

Abstract: In this paper, we investigate numerical methods for the phase-field surfactant model, which is a gradient flow system consisting of two nonlinearly coupled Cahn-Hilliard type equations. The main challenge in developing high-order efficient energy stable methods for this system results from the nonlinearity and the strong coupling in the two variables in the free energy functional. We propose two totally decoupled, linear and energy stable schemes based on the linear stabilization approach and an operator splitting technique. We rigorously prove that both schemes preserve the original energy dissipation law. The techniques employed in these schemes are then summarized into an innovative approach, which we call the mobility operator splitting (MOS), to design high-order decoupled energy stable schemes for a wide class of gradient flow systems. As a particular case, MOS allows different time steps for updating respective variables, leading to a multiple time-stepping strategy for fast/slow dynamics and thus improvement of computational efficiency. Various numerical experiments are presented to validate the efficiency and the desired properties of the proposed schemes. In addition, detailed phenomena in thin-film breaking processes can be clearly captured by using the proposed schemes.

[118] **The Random Feature Method for Solving Interface Problems**.

Xurong Chi. University of Science and Technology of China.

Abstract: Interface problems have long been a major focus of scientific computing, leading to the development of various numerical methods. Traditional mesh-based methods often employ time-consuming body-fitted meshes with standard discretization schemes or unfitted meshes with tailored schemes to achieve controllable accuracy and convergence rate. Along another line, mesh-free methods bypass mesh generation but lack robustness in terms of convergence and accuracy due to the low regularity of solutions. In this study, we propose a novel method for solving interface problems within the framework of the random feature method (RFM). This approach utilizes random feature functions in conjunction with a partition of unity as approximation functions, and solves a linear least-squares system to obtain the approximate solution. In the context of interface problems, two crucial components are incorporated into the RFM. Firstly, we utilize two sets of random feature functions on each side of the interface, allowing for the inclusion of low regularity or even discontinuous behaviors in the solution. Secondly, the construction of the loss function is based on the assessment of the partial differential equation, initial/boundary conditions, and the interface condition on collocation points. This approach ensures that these conditions are satisfied on an equal footing. Consequently, the challenges arising from geometric complexity primarily manifest in the generation of collocation points, a task amenable to standard methods. Importantly, the proposed method retains its meshfree characteristics and robustness when addressing problems featuring intricate geometries. We validate our method through a series of linear interface problems with increasingly complex geometrices, including two-dimensional elliptic and three-dimensional Stokes interface problems, a three-dimensional elasticity interface problem, a moving interface problem with topological change, a dynamic interface problem with large deformation, and a linear fluid-solid interaction problem with complex geometry. Our findings show that despite the solution often being only continuous or even discontinuous, our method not only eliminates the need for mesh generation but also maintains high accuracy, akin to the spectral collocation method for smooth solutions. Remarkably, for the same accuracy requirement, our method requires two to three orders of magnitude fewer degrees of freedom than traditional methods, demonstrating its significant potential for solving interface problems with complex geometries.

[119] **Wetting dynamics with surface binding**.

Xueping Zhao. University of Nottingham Ningbo China.

Abstract: Biomolecules, such as proteins and RNAs, can phase separate in the cytoplasm of cells to form biological condensates. Such condensates are liquid-like droplets that can wet biological surfaces such as membranes. Many molecules that can participate in phase separation can also bind to membrane surfaces. When a droplet wets such a surface, these molecules can diffuse both inside the droplet or in the bound state on the surface. How the interplay between surface binding and surface diffusion affects the wetting kinetics is not well understood. Here, we derive the governing equations using non-equilibrium thermodynamics by relating the diffusive fluxes and forces at the surface coupled to the bulk. We use our theory to study the spreading kinetics in the presence of surface binding and find that binding speeds up wetting by nucleating a droplet inside the surface. Our results are relevant both to non-biological systems and to condensates in living cells. They suggest that the wetting of droplets in living cells could be regulated by two-dimensional droplets in the surface-bound layer changing the binding affinity to biological surfaces.

[120] **An optimal error bound for shiftedCholeskyQR3 in oblique inner product**.

Weiguo Gao. Fu Dan University.

Abstract: The shiftedCholeskyQR3 algorithm has been proposed in [Fukaya et al., SIAM J. Sci. Comput., 42(2000), pp. A477–A503] as an optional choice of the orthogonalization algorithms recently. We extend the error analysis result for oblique inner product and show that the new error bound is optimal. We also discuss the loss of orthogonality and verify our conclusions through numerical experiments. This is joint work with Rentao Xu.

[121] **Understanding Condensation via Embedding Principle and Optimistic Estimate of Deep Neural Networks**.

Yaoyu Zhang. Shanghai Jiao Tong University.

Abstract: This talk focuses on the widely observed condensation phenomenon, i.e., neurons in a layer tends to align with one another., during the nonlinear training of deep neural networks (DNNs). To understand the origin of condensation, I will first introduce the Embedding Principle of loss landscape of DNNs that a DNN inherits all critical points of narrower DNNs. These inherited critical points are intrinsically "condensed" and able to attract trajectories nearby. To understand the generalization benefit of condensation, I will present the framework of optimistic estimate, which estimates the optimistic (smallest-possible) sample size for the recovery of nonlinear models. Under this framework, I will demonstrate how condensation facilitates the recovery of DNNs with a sample size close to the optimistic one.

[122] **Convergence rates for local dependent random variables**.

Zhuosong Zhang. Southern University of Science and Technology.

Abstract: This talk focuses on normal approximation under local dependence using Stein's method. Local dependence refers to the setting where specific subsets of random variables are independent within their respective "neighborhoods" but not outside. We provide a review of both Berry—Esseen bounds and Cramér-type moderate deviations for locally dependent random variables. Additionally, some applications will also be discussed.

[123] **On Mean-field super-Brownian motions**.

Jiayu Zheng. Shenzhen MSU-BIT University.

Abstract: The mean-field stochastic partial differential equation (SPDE) corresponding to a mean-field super-Brownian motion (sBm) is obtained and studied. In this mean-field sBm, the branching-particle lifetime is allowed to depend upon the probability distribution of the sBm itself, producing an SPDE whose space-time white noise coefficient has, in addition to the typical sBm square root, an extra factor that is a function of the probability law of the density of the mean-field sBm. This novel mean-field SPDE is thus motivated by population models where things like overcrowding and isolation can affect growth. A two step approximation method is employed to show existence for this SPDE under general conditions. Then, mild moment conditions are imposed to get uniqueness. Finally, smoothness of the SPDE solution is established under a further simplifying condition.

[124] **Phase transition in the EM scheme of an SDE driven by α-stable noises with $\alpha \in (0,2]$**.

Yu Wang. University of Macau.

Abstract: We study in this paper the EM scheme for a family of well-posed critical SDEs with the drift $-x\log(1+|x|)$ and α-stable noises. Specifically, we find that when the SDE is driven by a rotationally symmetric α-stable processes with α=2 (i.e. Brownian motion), the EM scheme is bounded in the $\mathrm{L}^\mathbf{2}$ sense uniformly w.r.t. the time. In contrast, if the SDE is driven by a rotationally symmetric α-stable process with $\alpha \in (0,2)$, all the β-th moments, with $\beta \in (0,\alpha)$, of the EM scheme blow up. This demonstrates a phase transition phenomenon as $\alpha \to 2$ We verify our results by simulations.

[125] **Multivariate high frequency realized volatility for sluggish trading**.

Zhi Liu. University of Macau.

Abstract: The high frequency financial data is stale, particularly for those days of sluggish trading. In this paper, considering the presence of bivariate price staleness, we study the problem of measuring the multivariate realized volatility of semi-martingales. We propose a consistent estimator of the integrated covariation and establish a unified limiting theory, which includes several existing results as special cases. Our results demonstrate that the idiosyncratic price staleness appear in the limit of the standard realized covariation, but the systematic price staleness has only an impact on the second order limiting behaviour. Moreover, we find that price staleness makes the standard realized covariation closer to zero than that without price staleness. Hence it explains the well-known Epps effect appropriately. We conduct extensive Monte Carlo studies to assess the finite sample performance of the proposed theory, and some empirical applications to real high-frequency data are considered to illustrate our theory.

[126] **Paths, Pasts, or More – a High-Frequency Perspective in Cryptocurrency Volatility**.

Jia Zhai. Xi'an Jiaotong Liverpool University.

Abstract: We empirically investigate whether the predictability of high-frequency volatility in mainstream cryptocurrencies depends on paths of returns, past volatilities, or the information contained within the limit order book. Initially, we demonstrate robust predictive accuracy across 5-, 15-, 30-, 45-, and 60-minute volatilities using both machine learning and linear models. Among these, the random forest model consistently achieves the highest R^2 across all frequencies. Our analysis reveals that high-frequency volatility exhibits dependencies on all three aspects. However, paths of returns and past volatilities exhibit the strongest influence on the predictive accuracy, while limit order book information contributes a comparatively weaker effect. Notably, models utilizing solely past volatility or paths of returns yielded markedly superior out-of-sample prediction accuracy compared to those incorporating extensive limit order book data. This compelling evidence suggests a more convenient and precise approach for measuring and observing market risk from a high-frequency perspective.

[127] **Generalized convergence for the Deep BSDE method**.

ZhiPeng Huang. Utrecht University.

Abstract: We are concerned with high-dimensional coupled FBSDE systems approximated by the deep BSDE method of Han et al. (2018). It was shown by Han and Long (2020) that the errors induced by the deep BSDE method admit a posteriori estimate depending on the loss function, whenever the backward equation only couples into the forward diffusion through the Y process. We generalize this result to fully-coupled drift coefficients, and give sufficient conditions for convergence under standard assumptions. The resulting conditions are directly verifiable for any equation. Consequently, our convergence analysis enables the treatment of FBSDEs stemming from stochastic optimal control problems. In particular, we provide a theoretical justification for the non-convergence of the deep BSDE method observed in recent literature, and present direct guidelines for when convergence can be guaranteed in practice. Our theoretical findings are supported by several numerical experiments in high-dimensional settings. This is a joint work with Balint Negyesi and Cornelis W. Oosterlee.

[128] **Total value adjustment of option valuation under CGMY Processes**.

Fengyan Wu. Chongqing University.

Abstract: The total value adjustment (XVA) is a collection of multiple value adjustments that have been applied to a variety of derivatives in the industry. A widely used pure jump Lévy process, the Carr-Geman-Madan-Yor (CGMY) process has been considered for pricing option with various value adjustments. Under a pure jump Lévy process, the value of derivatives satisfies a fractional partial differential equation (FPDE). We construct a method that combines Monte Carlo simulation of the CGMY process with a finite difference of FPDE to find the numerical approximation of exposure. Based on the numerical results, the XVA is computed by the financial exposure of the derivative value.

[129] **A finite element / spectral mixed approximation for the Stokes problem**.

Shinya Uchiumi. Hokkaido University.

Abstract: We propose a finite element/spectral mixed approximation for the Stokes problem. Numerical results of test problems show that this is precise for the problem having small viscosity compared to the standard P2/P1-finite element because of the higher order approximation of pressure. The resultant linear system is efficiently solved by the iterative method.

[130] **Insight of nonlinear elimination preconditioning from ODE theory viewpoint**.

Feng-Nan Hwang. National Central University.

Abstract: Nonlinear preconditioning is a powerful technique for accelerating the convergence of nonlinear iterative methods for solving large, sparse nonlinear systems of equations. It is beneficial for unbalanced non-linear systems where classical iterative methods, such as Newton-type with some globalization techniques, e.g., line search or trust region methods suffer from slow convergence issues. Strong local nonlinearity imposes severe constraints on step size selection, similar to stiff ordinary differential equations. An unacceptable time step size for a numerical integrator has been chosen because some components in the system change more rapidly than others. However, nonlinear preconditioning in conjunction with Newton-type methods is thriving as the solution algorithm for the nonlinear system, PDE, or algebraic-constrained optimization problems arising from flow simulation or flow control in the literature. A complete theoretical analysis of this technique is still open. Nevertheless, this talk tries to provide some heuristic understanding of the techniques by introducing some metrics, so-called stiffness ratios from the ordinary differential equation point of view, for measuring the unbalanced degree of nonlinear systems, which are analogous to the condition number of the coefficient matrix for linear systems for reflecting the quality of the matrix. Such information is hopeful in providing a guideline and analysis tool for designing a preconditioner for particular applications. A few numerical examples of recently introduced nonlinear elimination preconditioned inexact Newton algorithms are provided to prove the concept.

[131] **Cross-interactive residual smoothing for reducing the residual gap of block Lanczos-type iterative methods**.

Kensuke Aihara. Tokyo City University.

Abstract: Block Lanczos-type methods are effective iterative solvers for large sparse linear systems with multiple right-hand sides. However, the residual norms often oscillate, and the methods may have a large residual gap (the difference between the recursively updated residual and the explicitly computed residual), leading to a loss of attainable accuracy of the approximations. To overcome this problem, in this talk, we propose a novel residual smoothing scheme. The basic idea is that the primary and smoothed sequences of the approximations and residuals influence one another, thereby avoiding the severe propagation of rounding errors. Through rounding error analysis and numerical experiments, we demonstrate that the proposed approach is useful for reducing the residual gap and improving the attainable accuracy.

[132] **Continuous, discrete and ultradiscrete Burgers equation derived through the correlated random walk**.

Sennosuke Watanabe. The University of Fukuchiyama.

Abstract: The correlated random walk is known as a generalization of the well-known random walk. Since the time evolution of a random walk is equivalent to the discrete diffusion equation, the time evolution of a correlated random walk provides a kind of generalization of the discrete diffusion equation. In this talk, we will show a generalized discrete Burgers equation by applying an appropriate Cole-Hopf transformation to the generalized discrete diffusion equation. We also discuss continuous and ultradiscrete equations obtained by taking a continuous limit and applying an ultradiscretization, respectively, of the generalized discrete Burgers equation.

[133] **Functional Tipping Indicators in Stochastic Dynamical Systems vis Schrodinger Bridge**.

Ting Gao. HuazhongUniversityofScienceandTechnology.

Abstract: Action functionals between two meta-stable states in stochastic dynamical systems are good tools to study the critical transitions and tipping. We will present our recent findings on tipping indicators based on the Onsager- Machlup action functional and Schrodinger bridge. The latter also extends the transition paths to be pathway measures between two given invariant manifolds. To validate our framework, we apply our methodology to some neural models as well as real brain data, such as EEG and fMRI from epilepsy and Alzheimer's disease.

[134] **Hermite spectral method for multi-species Boltzmann equation**.

Yixiao Lu. Peking University.

Abstract: We introduce a numerical scheme for the full multi-species Boltzmann equation based on Hermite spectral method. With the proper choice of expansion centers for different species, a practical algorithm is derived to evaluate the complicated multi-species binary collision operator. New collision models are built by combining the quadratic collision model and the simple BGK collision model under the framework of the Hermite spectral method, which enables us to balance the computational cost and accuracy. Several numerical experiments are implemented to validate the dramatic efficiency of this new Hermite spectral method. Moreover, we can handle the problems with as many as 100 species, which is far beyond the capability of the state-of-art algorithms. This is a joint work with Ruo Li, Yanli Wang and Haoxuan Xu.

[135] **Understand how initialization affects inference ability of transformer network via network condensation**.

Zhiqing Xu. Shanghai Jiao Tong University.

Abstract: In this talk, we will discuss the condensation phenomenon in training neural networks and use condensation to understand transformer net- work in learning composite anchor function. We will show evidence that small initialization will lead to preference of inference results.

[136] **An asymptotic-preserving-based bi-fidelity method for kinetic- fluid modeling of mixture flows with distinct particle sizes and uncer- tainties**.

Yiwen Lin. Shanghai Jiao Tong University.

Abstract: Consider kinetic-fluid models for a mixture of flows, where the disperse phase is made of particles with distinct sizes. This leads to a system coupling the incompressible Navier–Stokes equations to the

Vlasov–Fokker–Planck equations. We first develop an asymptotic-preserving numerical scheme to approximate such multi-phase flow system. Then we develop an asymptotic- preserving-based bi-fidelity method for such system with random inputs, effi- ciently in both kinetic and hydrodynamic regimes. Numerical examples illustrate the accuracy and efficiency of the bi-fidelity method.

[137] **A Quasi Monte Carlo-Based Domain Decomposition Pre- conditioner for Efficiently Solving the Helmholtz Equation in Random Media**.

Yi Yu. Guangxi University.

Abstract: In this talk, we present a novel approach for efficiently solving the Helmholtz equation in random media by leveraging a quasi Monte Carlo method combined with new domain decomposition preconditioners. Given the random refractive index, employing the quasi Monte Carlo method yields a substan- tial number of sampling points. We first apply a machine learning algorithm (k-means) in probability space to partition the sampling points into distinct clusters. Within each cluster, a benchmark point is selected. In the physical space, we design domain decomposition preconditioners tailored explicitly to these benchmark points. Consequently, all other points within the same cluster utilize the preconditioner associated with the benchmark point for solution, a methodology referred to as 'nearby preconditioning'. We show that using the above techniques, the computation cost for the random Helmholtz equation can be greatly reduced.

[138] **On asymptotic-preserving neural networks for the semiconductor Boltzmann equation under diffusive scaling**.

Liu Liu. Chinese University of Hong Kong.

Abstract: Kinetic equations describe the non-equilibrium dynamics of a system composed of a large number of particles, and have wide applications in rarefied gas, plasma physics, astrophysics, etc. The multiple scales in kinetic equations bring huge numerical challenges especially when the Knudsen number is small. In this work, we develop asymptotic-preserving neural networks to study the semiconductor Boltzmann-(Poisson) system, in a micro-macro decomposition framework. The main purpose of this approach is to enhance the performance of standard PINNs for solving multiscale PDEs. We will provide theoretical results on the convergence of loss function and its neural network approximated solutions. Several numerical experiments for forward and inverse problems will be shown.

[139] **Recent progresses of the Cholesky QR type algorithms for the QR factorization of a tall and skinny matrix**.

Takeshi Fukaya. Hokkaido University.

Abstract: The Cholesky QR algorithm has been known as a fast algorithm that computes the QR factorization of a tall and skinny matrix in recent computational environments, however, it has been not widely used in practical due to its numerical instability. In the recent decade, several attempts that improve the numerical stability and accuracy of the Cholesky QR algorithm have been proposed, and the resulting algorithms are now competitive to other algorithms including the Householder QR algorithm. In this talk, an overview of the recent improvements of the Cholesky QR type algorithms are presented together with the performance results on supercomputer systems.

[140] **An optimal error bound for shiftedCholeskyQR3 in oblique inner product**.

Weiguo Gao. TBD.

Abstract: TBD.

[141] **Quaternion reorthogonalization method with application to color image processing**.

Zhigang Jia. Jiangsu Normal University.

Abstract: The loss of orthogonality has become the key issue of solving the large-scale quaternion eigenvalue problem. However, there are still lack of efficient quaternion reorthogonalization methods. In this talk, we introduce a new reorthogonalization scheme of the computed quaternion vectors and embed it into several

new algoirthms of quaternion matrix eigenalue problem. The proposed algorithms are applied to color image processing, and the experimental results demonstrate their efficiency and advantages to the existing algorithms.

[142] **Householder orthogonalization with a nonstandard inner product**.

Meiyue Shao. Fudan University.

Abstract: Householder orthogonalization plays an important role in numerical linear algebra. It attains perfect orthogonality regardless of the conditioning of the input. However, in the context of a non-standard inner product, it becomes difficult to apply Householder orthogonalization, partly due to the lack of an initial orthonormal basis. We propose strategies to overcome this obstacle and discuss algorithms and variants of Householder orthogonalization with a non-standard inner product. Theoretical analysis and numerical experiments demonstrate that our approach is numerically stable under mild assumptions.

[143] **DPK: Deep Neural Network Approximation of the First Piola-Kirchhoff Stress** .

Cheng Yuan. Wuhan University.

Abstract: This talk presents a specific network architecture for approximation of the first Piola-Kirchhoff stress. The neural network enables us to construct the constitutive relation based on both macroscopic observations and atomistic simulation data. In contrast to traditional deep learning models, this architecture is intrinsic symmetric, guarantees the frame-indifference and material-symmetry of stress. Specifically, we build the approximation network inspired by the Cauchy-Born rule and virial stress formula. Several numerical results and theory analyses are presented to illustrate the learnability and effectiveness of our network.

[144] **A threshold dislocation dynamics method**.

Xiaoxue Qin. Shanghai University.

Abstract: We propose a threshold dynamics method for dislocation dynamics in a slip plane, in which the spatial operator is essentially an anisotropic fractional Laplacian. We show that this threshold dislocation dynamics method is able to give two correct leading orders in dislocation velocity, including both the $O(\log \epsilon)$ local curvature force and the $O(1)$ nonlocal force due to the long-range stress field generated by the dislocations as well as the force due to the applied stress, where ϵ is the dislocation core size, if the time step is set to be $\Delta t = \epsilon$. This generalizes the available result of threshold dynamics with the corresponding fractional Laplacian, which is on the leading order $O(\log \Delta t)$ local curvature velocity under the isotropic kernel. We also propose a numerical method based on spatial variable stretching to correct the mobility and to rescale the velocity for efficient and accurate simulations, which can be applied generally to any threshold dynamics method. We validate the proposed threshold dislocation dynamics method by numerical simulations of various motions and interaction of dislocations.

[145] **Random batch molecular dynamics method for fully periodic and quasi-2D periodic systems** .

Jiuyang Liang. Shanghai Jiao Tong University.

Abstract: The development of efficient methods for long-range systems plays a crucial role in all-atom molecular dynamics simulations of biomolecules and materials science. This presentation provides an overview of recent advancements in random batch molecular dynamics, encompassing random-batch Ewald and random-batch sum-of-Gaussians (SOG) methods for both fully periodic and quasi-2D partially periodic systems. These algorithms leverage the random minibatch strategy for force calculation between particles, resulting in an order N algorithm. They utilize Ewald or SOG splitting of the Coulomb kernel and employ random importance sampling for the Fourier part, thereby eliminating the need for FFT and significantly enhancing the scalability of molecular simulations. The treatment of short-range interactions using the random batch approach, energy-stable schemes, and software development efforts are also discussed. Numerical examples and applications are presented to demonstrate the compelling performance of these methods.

[146] **A kernel-splitting algorithm framework for interacting particle systems under quasi-2D confinement** .

Zecheng Gan. The Hong Kong University of Science and Technology.

Abstract: Quasi-2D Coulomb systems are of fundamental importance and have attracted much attention in many areas nowadays. Their reduced symmetry gives rise to interesting collective behaviors, but also brings great challenges for particle-based simulations. Here, we propose a novel algorithm framework to address the $\mathcal{O}(N^2)$ simulation complexity associated with the long-range nature of Coulomb interactions. First, we introduce an efficient Sum-of-Exponentials (SOE) approximation for the long-range kernel associated with Ewald splitting, achieving uniform convergence in terms of inter-particle distance, which reduces the complexity to $\mathcal{O}(N^{7/5})$. We then introduce a random batch sampling method in the periodic dimensions, the stochastic approximation is proven to be both unbiased and with reduced variance via a tailored importance sampling strategy, further reducing the computational cost to $\mathcal{O}(N)$. The performance of our algorithm is demonstrated via varies numerical examples. Notably, it achieves a speedup of $2 \sim 3$ orders of magnitude comparing with Ewald2D method, enabling molecular dynamics (MD) simulations with up to 10^6 particles on a single core. The present approach is therefore well-suited for large-scale particlebased simulations of Coulomb systems under confinement, making it possible to investigate the role of Coulomb interaction in many practical situations.

[147] **Non-local non-linear PDE models arising in fluid mechanics**.

Hisashi Okamoto. Gakushuin University.

Abstract: Fluid mechanics offers mathematicians difficult computational problems. Some are too difficult even for advanced computers. Therefore many ‘model equations’ have been proposed. Here I will survey some of them in a form which I believe to be friendly to EASIAM members. Since I will focus on incompressible fluid, non-local equations play important roles.

[148] **Traveling singularities in the fast-diffusion equation**.

Eiji Yanagida. The University of Tokyo.

Abstract: We consider traveling solutions of the fast diffusion equation. By assuming a special form of traveling solutions, the problem is reduced to an ODE on a finite interval. We classify solutions depending on the shape of singular sets, and show the existence of traveling singular solutions of various types. It is shown that the structure of traveling singular solutions depends on a parameter characterizing the diffusivity, and there appear some critical values depending on the spatial dimension. The results are applied to show the existence of more general solutions with dynamic singularities.

[149] **On the convergence of the numerical blow-up time for a rescaling algorithm**.

Chien-Hong Cho. National Sun Yat-sen University.

Abstract: Berger and Kohn (1988) proposed an algorithm to compute approximate blow-up times for those evolution equations whose solutions blow up in a finite time and possess a scaling invariance property. Later, Anada et al. (2018) used this algorithm to compute the blow-up rates of various blow-up problems which turned out to be very effective. However, the convergence analysis for this algorithm seemed to be not well-studied. In this talk, we analyze the numerical implementation for this algorithm via a nonlinear ODE blow-up problem. The convergence order of the numerical blow-up time is also verified.

[150] **Linear vs. nonlinear speed selection of the front propagation into unstable states**.

Dongyuan Xiao. Nankai University.

Abstract: In this paper, we mainly consider the speed selection problem for the classical Lotka-Volterra competition system. By investigating the change of decay rates of propagation fronts, we propose a sufficient and necessary condition for this long-standing problem, which reveals the essence of propagation phenomena. Furthermore, through the comparison principle, our result can be extended to more general monostable dynamical systems, such as the integro-differential equation.

[151] **ODE-based Sampling and Generative Models**.

Zhao Ding. Wuhan University.

Abstract: In this presentation, we will focus on a unit-time probability ODE flow that serves as a bridge between a Gaussian measure and a desired target measure. This ODE system finds application in sampling and

generation tasks. For sampling, we can acquire the velocity field either analytically or through Monte Carlo approximation using Gaussian samples. As for generation, we employ a non-parametric regression approach to estimate the velocity field. Subsequently, we solve the ODE system numerically using discretization methods like Euler's method. Furthermore, we employ deep neural networks to model the characteristics along which the probability density transport can be described by the ODE. This enables us to develop a characteristic generator for one-step generation. We establish the non-asymptotic error for the generated distribution in 2-Wasserstein distance under reasonable conditions. To demonstrate the efficacy of our approach, we conduct experiments on synthetic and real-world datasets, showcasing its performance.

[152] **Density-equalizing Quasiconformal maps with applications**.

Zhiyuan LYU. The Chinese University of Hong Kong.

Abstract: We present innovative approaches to compute bijective density-equalizing quasi-conformal maps for open and closed surfaces. Traditional density-equalizing maps overlook bijectivity and local geometric distortions, focusing mainly on simply connected open surfaces. To overcome these limitations, our methods combine density diffusion with quasi-conformal theory, controlling distortion and ensuring bijectivity. By formulating an energy minimization problem involving the Beltrami coefficient, we balance distortions and preserve the bijective. For surfaces with multiple components, we develop an iterative scheme optimizing the target planar circular domain and the density-equalizing quasi-conformal map. Our methods incorporate landmark constraints for consistent feature alignment. By manipulating population parameters, diverse surface maps can be generated. Extensive testing on synthetic and real-world examples demonstrates efficacy in computer graphics and medical imaging.

[153] **A deep neural network framework for dynamic multi-valued mapping estimation and its applications**.

Geng Li. The Chinese University of Hong Kong.

Abstract: This paper addresses the problem of modeling and estimating dynamic multi-valued mappings. While most mathematical models provide a unique solution for a given input, real- world applications often lack deterministic solutions. In such scenarios, estimating dynamic multi- valued mappings is necessary to suggest different reasonable solutions for each input. This paper introduces a deep neural network framework incorporating a generative network and a classification component. The objective is to model the dynamic multi-valued mapping between the input and output by providing a reliable uncertainty measurement. Generating multiple solutions for a given input involves utilizing a codebook comprising discrete variables. These variables are fed into a generative network along with the input, producing various output possibilities. The discreteness of the variables enables efficient estimation of the output's conditional probability distribution for any given input using a classifier. By jointly optimizing the discrete codebook and its uncertainty estimation during training using a specially designed loss function, a highly accurate approximation is achieved. The effectiveness of our proposed framework is demonstrated through its application to various imaging problems, using both synthetic and real imaging data. Experimental results show that our framework accurately estimates the dynamic multi-valued mapping with uncertainty estimation.

[154] **DEEP ELASTIC INTERACTION ENERGY APPROACH FOR IMAGE PROCESSING**.

Yaxin FENG. Hong Kong University of Science and Technology.

Abstract: Deep learning techniques have shown success in image processing area since their strong capability on extracting features and patterns from large amount of data. The commonly used pixel-wise loss functions result in a bottleneck to achieve high segmentation precision for complicated geometry structures, e.g. long-thin or multi-scale objects. For instance, under the supervision of the pixel-wise losses, the predicted thin blood vessels in retinal images are often disconnected or even missed, and the detected lanes in diverse and complex driving scenes such as crowded environment or bad illumination are likely to be blurry. We propose a topology-aware deep training strategy to address these problems. In our approach, the neural network learns the target region under the guidance of the elastic interaction energy between the predicted boundaries and the ground truth. When the energy reaches to the minimum, the prediction will shrink to the correct position. Our method significantly improves the segmentation of geometrically complex objects.

[155] **Automatic Landmark Detection and Registration of Brain Cortical Surfaces via Quasi-Conformal Geometry and Convolutional Neural Networks**.

Yuchen Guo. The Chinese University of Hong Kong.

Abstract: In medical imaging, surface registration is extensively used for performing systematic comparisons between anatomical structures, with a prime example being the highly convoluted brain cortical surfaces. To obtain a meaningful registration, a common approach is to identify prominent features on the surfaces and establish a low-distortion mapping between them with the feature correspondence encoded as landmark constraints. Prior registration works have primarily focused on using manually labeled landmarks and solving highly nonlinear optimization problems, which are time-consuming and hence hinder practical applications. In this work, we propose a novel framework for the automatic landmark detection and registration of brain cortical surfaces using quasi-conformal geometry and convolutional neural networks. We first develop a landmark detection network (LD-Net) that allows for the automatic extraction of landmark curves given two prescribed starting and ending points based on the surface geometry. We then utilize the detected landmarks and quasi-conformal theory for achieving the surface registration. Specifically, we develop a coefficient prediction network (CP-Net) for predicting the Beltrami coefficients associated with the desired landmark-based registration and a mapping network called the disk Beltrami solver network (DBS-Net) for generating quasi-conformal mappings from the predicted Beltrami coefficients, with the bijectivity guaranteed by quasi-conformal theory. Experimental results are presented to demonstrate the effectiveness of our proposed framework. Altogether, our work paves a new way for surface-based morphometry and medical shape analysis.

[156] **Nonlinear differential equation model for vascular networks**.

Tetsuji Tokihiro. Musashino University.

Abstract: Based on recent in vitro experiments, we propose a mathematical model which assumes that the elongation and bifurcation of blood vessels during angiogenesis are determined by the density of endothelial cells at the tip of the vascular network, and describes the dynamical changes in vascular network formation using a system of simultaneous ordinary differential equations. The characteristics of the obtained patterns are analysed using multifractal dimension and other techniques.

[157] **Bifurcation structure of stationary solutions of a 1D Phase-Field equation**.

Tatsuki Mori. Musashino University.

Abstract: We consider the stability of solutions to a stationary problem in a one-dimensional phase-field model. Recently, Mori-Tasaki-Tsujikawa-Yotsutani (2022) showed that the global bifurcation diagrams of stationary solutions to the model and bifurcation diagrams include the secondary bifurcation point where symmetric breaking occurs and curves that connect a limit of boundary layer solutions to the other limit of internal layer solutions. In this presentation, we will report the results of the stability of symmetric solutions and solutions after the secondary bifurcation.

[158] **Exact solutions to nonlinear partial differential equations with singular integral terms and their application to traffic flow**.

Kohei Higashi. Musashino University.

Abstract: We introduce the way that nonlinear partial differential equations with singular integrals and their solutions are derived by imposing analyticity conditions on equations in the complex domain. Utilizing this method to construct the exact solutions, we analyze traffic flow phenomena by employing the exact solution of a traffic flow model with a singular integral, which is considered an extension of the Burgers equation. We explain that the density gradient changes and that deadlock phenomena occurs depending on the parameters.

[159] **The blow-up boundary for systems of semilinear wave equations**.

Takiko Sasaki. Musashino University.

Abstract: In this talk, we consider a blow-up curve for systems of semilinear wave equations with different propagation speeds in one space dimension. The blow-up curve has been studied from the view point of its

differentiability and singularity. We show that the blow-up curve has a singular point under suitable initial conditions. We also show some numerical examples of blow-up curves.

[160] **Conservation laws for Hamiltonian systems**.

Hongkun Zhang. The Great Bay University.

Abstract: Hamiltonian systems, foundational in classical mechanics, offer a robust framework for comprehending the evolution of physical systems. At the heart of this framework lie the conservation laws, emerging from the inherent symmetries of these systems. This talk delves deep into the core principles of Hamiltonian mechanics and strives to bridge the divide between machine learning and tangible real-world applications.

[161] **Data-driven model selections of interacting particle dynamics via Gaussian processes with uncertainty quantification**.

Jinchao Feng. Great Bay University.

Abstract: In this talk, I will introduce a data-driven method to identify a comprehensive second-order particle-based model, which integrates numerous advanced models for simulating aggregation and collective behaviors of agents with comparable sizes and shapes. The model is represented as a high-dimensional set of ordinary differential equations, parameterized by dual interaction kernels that evaluate the coordination of positions and velocities. We propose a Gaussian Process (GP)-based methodology for estimating the model parameters, employing two separate GP priors for the latent interaction kernels, which are calibrated against both dynamical and observational data. This approach yields a nonparametric model for interacting dynamical systems, incorporating uncertainty quantification. Additionally, we provide a theoretical analysis to elucidate our method and assess conditions necessary for kernel recovery. The efficacy of our approach is validated through applications to various prototype systems, emphasizing system order and interaction type selection.

[162] **Deep Learning method for counterparty risk of high-dimensional options.**

Gangnan Yuan. Great Bay University.

Abstract: In this talk, we present a novel machine learning approach to estimate the counterparty risk of high-dimensional American options based on modified Gaussian process regression (GPR). We incorporate deep kernel learning and sparse variational Gaussian processes to address the challenges traditionally associated with GPR. These challenges include its diminished reliability in high-dimensional scenarios and the excessive computational costs associated with processing extensive numbers of simulated paths. Our findings indicate that the proposed method surpasses the performance of the least squares Monte Carlo method in high-dimensional scenarios, particularly when the underlying assets are modeled by Merton's jump diffusion model. Moreover, our approach does not exhibit a significant increase in computational time as the number of dimensions grows. Consequently, this method emerges as a potential tool for alleviating the challenges posed by the curse of dimensionality.

[163] **Topological filtering of a signal over a network**.

Matiasde Jong van Lier. Kyushu University.

Abstract: Persistent homology provides crucial topological insights into datasets, where each topological feature is depicted by an interval, with its length representing the lifespan of the feature. Features with brief lifespans are often seen as noise, whereas those enduring longer are acknowledged as meaningful attributes of the dataset. Leveraging this perspective, we propose a novel method for topologically simplifying functions defined over the nodes of planar graphs. This method entails filtering persistence above a specified threshold in the persistence diagram and computing a new function with this filtered diagram as its persistence diagram. The result is a refined function that preserves the topologically significant aspects of the original while discarding what may be construed as topological noise. We demonstrate the effectiveness of our approach through practical applications involving signals over a network.

[164] **Analyzing representational capacity: determinantal point processes with symmetric vs non-symmetric kernels**.

Sebastian Graiff. Kyoto University Institute for Advanced Study, Japan.

Abstract: A determinantal point process (DPP) is a probabilistic model for subsets of a set of N items, parameterized by an N times N matrix—the kernel. The probability of each subset correlates directly with the determinant of the submatrix indexed by the given subset. Due to their inherent simplicity and effectiveness, DPPs have been adopted in machine learning for applications such as recommender systems and data summarization. Historically, they were defined on positive semi-definite (symmetric) kernels, which inherently promote a repulsive interaction among the items, in the sense that, selecting one item reduces the likelihood of selecting nearby others. However, it is also possible to use non-symmetric kernels which relax the repulsiveness in specific scenarios. In practice, when modeling a dataset with DPPs, one can opt for either symmetric or non-symmetric kernels. Each model has a different number of free parameters, and we propose to analyze them by taking this into account. In this presentation, we present quantitative findings that compare the representational capacities of the two types of DPPs, in terms of the degree of freedom.

[165] **A comprehensive study on zero-background solitons of the sharp-line Maxwell-Bloch equations**.

Sitai Li. Xiamen University.

Abstract: This work is devoted to systematically study general N-soliton solutions possibly containing multiple degenerate soliton groups (DSGs), in the context of the sharp-line Maxwell-Bloch equations with a zero background. We also show that results can be readily migrated to other integrable systems, with the same non-self-adjoint Zakharov-Shabat scattering problem or alike. Results for the focusing nonlinear Schrodinger equation and the complex modified Korteweg-De Vries equation are obtained as explicit examples for demonstrative purposes. A DSG is a localized coherent nonlinear traveling-wave structure, comprised of inseparable solitons with identical velocities. Hence, DSGs are generalizations of single solitons (considered as 1-DSGs), and form fundamental building blocks of solutions of many integrable systems. We provide an explicit formula for an N-DSG and its center. With the help of the Deift-Zhou's nonlinear steepest descent method, we prove the localization of DSGs, and calculate the long-time asymptotics for an arbitrary N-soliton solutions. It is shown that the solution becomes a linear combination of multiple DSGs in the distant past and future, with explicit formulae for the asymptotic phase shift for each DSG. Other generalizations of a single soliton are also discussed, such as Nth-order solitons and soliton gases. We prove that every Nth-order soliton can be obtained by fusion of eigenvalues of N-soliton solutions, with proper rescalings of norming constants, and every soliton-gas solution can be considered as limits of N-soliton solutions as $N \to +\infty$. Certain properties of Nth-order solitons and soliton gases are obtained as well.