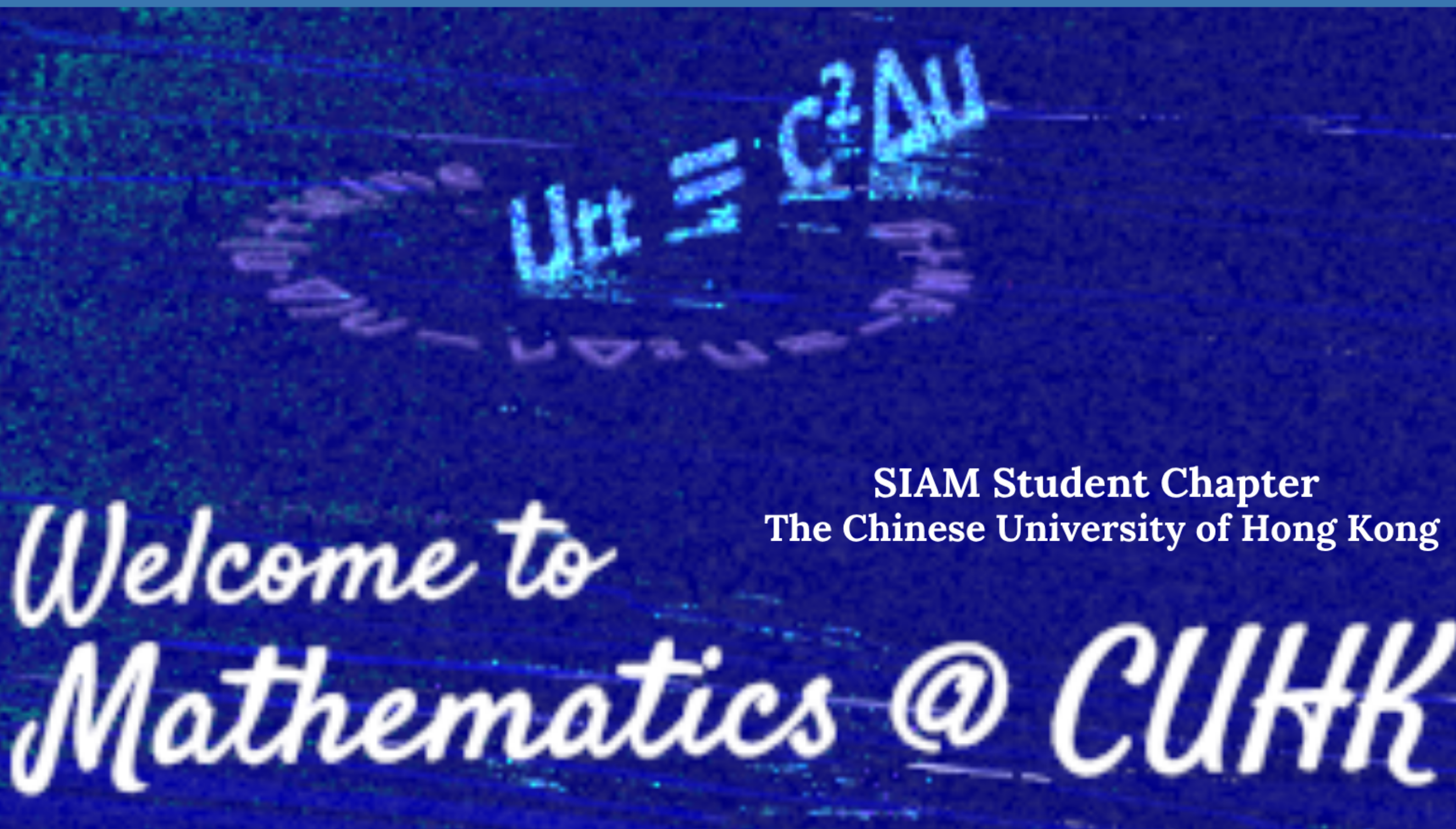
DEPARTMENT OF MATHEMATICS
THE CHINESE UNIVERSITY OF HONG KONG

2025 HKSIAM

STUDENT CHAPTER MINISYMPOSIUM

10-11 July 2025



SIAM Student Chapter
The Chinese University of Hong Kong

Welcome Message

We are thrilled to welcome you to the 2025 HKSIAM Student Chapter Minisymposium. This event brings together young researchers and postgraduate students from diverse institutions to share their work, exchange ideas, and foster collaboration.

Through engaging discussions and knowledge-sharing, we hope to strengthen connections among peers from CUHK and beyond, creating a vibrant network of aspiring researchers.

We wish you an enlightening and rewarding experience, filled with insightful sessions and meaningful interactions. Enjoy the event, and thank you for being part of it!

Organizing Committee

Prof. Eric Chung, The Chinese University of Hong Kong

Xingguang Jin, The Chinese University of Hong Kong

Abd'gafar Tunde Tiamiyu, The Chinese University of Hong Kong

CUHK SCI

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Schedule

SC01 July 10 2025, Thursday Room 201, CYT	**Chair: Xingguang Jin**
	11:10 - 11:40 Kota Takeda *Error analysis of the ensemble Kalman filter for chaotic dynamical systems with covariance inflation techniques*
	11:40 - 12:10 Yueqi Wang *Numerical homogenization for time-harmonic Maxwell equations in heterogeneous media with large wavenumber*
	12:10 - 12:40 ZeXian Li *Optimal Quantum Gate Cost for Block-Encoding Classical Matrices*
	12:40 - 12:50 **Group Photo**
SC02 July 10 2025, Thursday Room 201, CYT	**Chair: Yueqi Wang**
	16:30 - 17:00 Chenhao Lu *On the Eigenvalue Rigidity of the Jacobi Unitary Ensembles*
	17:00 - 17:30 Xingguang Jin *Efficient numerical method for the Schrödinger equation with high-contrast potential*
	17:30 - 18:00 Qingle Lin *Optimizing Coarse Propagators in Parareal Algorithms*
SC03 July 11 2025, Friday Room 203, CYT	**Chair: Abd'gafar Tunde Tiamiyu**
	10:20 - 10:50 Zhenyi Zhu *Deep Learning for Solving PDEs*
	10:50 - 11:20 Xiao Meng *Analysis of a Diffusive SIR Model on Metric Graph and Sub-domains*
	11:20 - 11:50 Yixuan Zhang *A Smoothing Implicit Gradient Algorithm for Optimization with Parametric Variational Inequality Constraints on a Moving Polyhedron*
	11:50 - 12:20 Tsz Ching Chow *Inertial Proximal Difference-of-Convex Algorithm with Convergent Bregman Plug-and-Play for Nonconvex Imaging*
SC04 July 11 2025, Friday Room LT1, CYT	**Chair: Xiao Meng**
	14:00 - 14 :30 Yuchen Huang *Boojum type singularities of weak anchoring liquid crystals around a particle*
	14:30 - 15:00 Tsz Lok Ip *Quasi-Conformal Convolution: A Learnable Convolution for Deep Learning on Riemann Surfaces*
	15:00 - 15:30 Trung Hieu Giang *Existence and uniqueness results for a nonlinear shell model*
	15:30 - 16:00 Zhen Hao *Asymptotic-Preserving Schemes for Boltzmann Mixture Models with Disparate Masses*

Kota Takeda

Nagoya University

Error analysis of the ensemble Kalman filter for chaotic dynamical systems with covariance inflation techniques

In this talk, we focus on the sequential state estimation problems for a class of chaotic dynamical systems on Hilbert spaces, including the two-dimensional Navier–Stokes equations and the Lorenz 63 and 96 models. Data assimilation combines numerical models with observational data to estimate the system state, representing the estimate as a probability distribution. For nonlinear dynamical systems, the ensemble Kalman filter (EnKF) is commonly employed to approximate the mean and covariance of this distribution, thereby capturing the uncertainty in the state estimate. In practice, ad-hoc numerical techniques known as covariance inflation are applied to stabilize the EnKF, despite a lack of rigorous theoretical justification. We analyze the state estimation error when the EnKF is applied to such chaotic dynamical systems, with particular attention to the role of covariance inflation in ensuring the accuracy.

Yueqi Wang

The University of Hong Kong

Numerical homogenization for time-harmonic Maxwell equations in heterogeneous media with large wavenumber

We propose a new numerical homogenization method based upon the edge multiscale method for time-harmonic Maxwell equations in heterogeneous media with large wavenumber. Numerical methods for time-harmonic Maxwell equations in homogeneous media with large wavenumber is very challenging due to the so-called pollution effect: the mesh size should be much smaller than the reciprocal of the wavenumber to obtain a solution with certain accuracy. It is much more challenging for the case with heterogeneous media that occurrs often in the practical applications, such as the simulation of metamaterial, since one has to resolve the heterogeneity for a reasonable numerical solution. We devise a novel approach that do not resolve the heterogeneity in the coefficient and has a mesh size linearly depends on the reciprocal of the wavenumber, which has a first order convergence rate. Extensive numerical tests are provided to verify our theoretical findings.

Zexian Li

The Hong Kong Polytechnic University

Optimal Quantum Gate Cost for Block-Encoding Classical Matrices

The optimal cost of encoding classical matrices into quantum gates can be characterized in two ways: minimal circuit depth and minimal circuit size. This presentation examines two key scenarios:
1. The conditions under which encoding a general matrix achieves minimal circuit size;
2. The conditions under which encoding a sparse matrix achieves minimal circuit depth.

Chenhao Lu

City University of Hong Kong

On the Eigenvalue Rigidity of the Jacobi Unitary Ensembles

This project aims to establish the eigenvalue rigidity of Jacobi unitary ensembles. We want to find an optimal bound for the fluctuations of eigenvalues away from their limiting values. Different from the Gaussian unitary ensemble, hard edges appear in the Jacobi case, hence the eigenvalues are expected to concentrate near the edges. The main idea of our proof is to combine the extreme value theory of log-correlated Gaussian field, especially the fractal properties of the Gaussian multiplicative chaos measure, together with asymptotic analysis of the Hankel determinants with Fisher-Hartwig singularities, where Riemann-Hilbert approach is adopted. Some estimates of the exponential moments of an asymptotically Gaussian process are also obtained.

Xingguang Jin

The Chinese University of Hong Kong

Efficient numerical method for the Schrödinger equation with high-contrast potential

We developed constraint energy minimization generalized multiscale finite element method (CEM-GMsFEM) in the framework of Crank-Nicolson (CN) discretisation in time for Schrödinger equations with multiscale potential functions. The localized multiscale basis functions are constructed by addressing the spectral problem and a constrained energy minimization problem related to the Hamiltonian norm. A first-order convergence in the energy norm and second-order convergence in the \$L^2\$ norm for our numerical scheme are shown, with a relation between the oversampling number in the CEM-GMsFEM method, the spatial mesh size and the semiclassical parameter provided. Several numerical examples, including 1D and 2D in space, with high-contrast potential, are conducted to demonstrate the efficiency and accuracy of our proposed scheme.

Qingle Lin

The Hong Kong Polytechnic University

Optimizing Coarse Propagators in Parareal Algorithms

The parareal algorithm represents an important class of parallel-in-time algorithms for solving evolution equations and has been widely applied in practice. To achieve effective speedup, the choice of the coarse propagator in the algorithm is vital. In this work, we investigate the use of {optimized} coarse propagators. Building upon the error estimation framework, we present a systematic procedure for constructing coarse propagators that enjoy desirable stability and consistent order. Additionally, we provide preliminary mathematical guarantees for the resulting parareal algorithm. Numerical experiments on a variety of settings, e.g., linear diffusion model, Allen-Cahn model, and viscous Burgers model, show that the optimizing procedure can significantly improve parallel efficiency when compared with the more ad hoc choice of some conventional and widely used coarse propagators.

Zhenyi Zhu

The Chinese University of Hong Kong

Deep Learning for Solving PDEs

We explore innovative deep learning methods to solve complex partial differential equations (PDEs), including the semiconductor Boltzmann equation, time-dependent PDEs, and the semiclassical Schrödinger equation's moment system. Our approaches—Asymptotic-Preserving Neural Networks (APNNs), PhysicsSolver, and a two-stage neural network—address multiscale challenges, temporal extrapolation, and multi-phase closures. APNNs ensure scale uniformity, PhysicsSolver merges physical insights with predictive power, and the two-stage method learns moment relationships to close systems. Supported by convergence analysis and validated through numerical tests, these methods demonstrate high accuracy and efficiency, even with sparse data, advancing deep learning's role in PDE solutions.

Xiao Meng

Hong Kong Baptist University

Analysis of a Diffusive SIR Model on Metric Graph and Sub-domains

In this work, we analyze a diffusive SIR model formulated on a coupled structure consisting of metric graphs and subdomains. A weak formulation is developed to describe the dynamics within the subdomains, along the edges of the graph, and at the vertices where the two structures interact. The well-posedness of the system is established, including the existence and uniqueness. Furthermore, the adjoint system is derived, and the associated optimality conditions are obtained, leading to a coupled system of state and adjoint equations. These results provide a mathematical framework for the analysis of diffusive SIR models on a hybrid structure, with potential applications to modeling and managing the spatial spread of epidemics.

Yixuan Zhang

The Hong Kong Polytechnic University

A Smoothing Implicit Gradient Algorithm for Optimization with Parametric Variational Inequality Constraints on a Moving Polyhedron

This work introduces a Smoothing Implicit Gradient Algorithm with Inexactness (SIGAI) to address optimization problems constrained by Parametric Variational Inequalities (PVI) defined on a moving polyhedron. Unlike prior works limited to fixed feasible sets, SIGAI handles moving constraints where the feasible region evolves with parameters. Key innovations of the proposed SIGAI framework include: (i) smoothing approximation of the projection operator with vanishing smoothing parameters; (ii) inexact sub-problem solutions requiring only finite iterations per sub-problem; and (iii) convergence guarantees to stationary points and convergence rate characterization. Numerical experiments validate the algorithm's convergence and efficiency, with applications to real-world portfolio management problems.

Tsz Ching Chow

The Chinese University of Hong Kong

Inertial Proximal Difference-of-Convex Algorithm with Convergent Bregman Plug-and-Play for Nonconvex Imaging

Imaging tasks are typically tackled using a structured optimization framework. We delve into a class of algorithms for difference-of-convex (DC) structured optimization, focusing on minimizing a DC function and possibly a nonconvex function. Existing DC algorithms (DCA) often fail to handle nonconvex functions or exhibit slow convergence rates effectively. We propose a novel inertial proximal DC algorithm in Bregman geometry, named iBPDCA, designed to address nonconvex terms and enhance convergence speed through inertial techniques. We provide a detailed theoretical analysis, establishing both subsequential and global convergence of iBPDCA via the Kurdyka-Łojasiewicz property. Additionally, we introduce a Plug-and-Play variant, PnP-iBPDCA, which employs a deep neural network-based prior for greater flexibility and robustness while ensuring theoretical convergence. We also establish that the Gaussian gradient step denoiser used in our method is equivalent to evaluating the Bregman proximal operator for an implicitly weakly convex function. We extensively validate our method on Rician noise and phase retrieval and demonstrate state-of-the-art performance.

Yuchen Huang

The Chinese University of Hong Kong

Boojum type singularities of weak anchoring liquid crystals around a particle

We study the one constant limit in the Landau-de Gennes theory where the generalized Rapini-Papoular surface energy density is imposed in the particle surface, and the far-field condition is imposed in the infinity. Under the axial ansatz, we show that singularities of the director field will occur as the boojum type on the antipodes when the anchoring strength is sufficiently large.

Tsz Lok Ip

The Chinese University of Hong Kong

Quasi-Conformal Convolution: A Learnable Convolution for Deep Learning on Riemann Surfaces

Deep learning on non-Euclidean domains is important for analyzing complex geometric data that lacks common coordinate systems and familiar Euclidean properties. A central challenge in this field is to define convolution on domains, which inherently possess irregular and non-Euclidean structures. In this work, we introduce Quasi-conformal Convolution (QCC), a novel framework for defining convolution on Riemann surfaces using quasi-conformal theories. Each QCC operator is linked to a specific quasi-conformal mapping, enabling the adjustment of the convolution operation through manipulation of this mapping. By utilizing trainable estimator modules that produce Quasi-conformal mappings, QCC facilitates adaptive and learnable convolution operators that can be dynamically adjusted according to the underlying data structured on Riemann surfaces. QCC unifies a broad range of spatially defined convolutions, facilitating the learning of tailored convolution operators on each underlying surface optimized for specific tasks. Building on this foundation, we develop the Quasi-Conformal Convolutional Neural Network (QCCNN) to address a variety of tasks related to geometric data. We validate the efficacy of QCCNN through the classification of images defined on curvilinear Riemann surfaces, demonstrating superior performance in this context. Additionally, we explore its potential in medical applications, including craniofacial analysis using 3D facial data and lesion segmentation on 3D human faces, achieving enhanced accuracy and reliability.

Trung Hieu Giang

City University of Hong Kong

Existence and uniqueness results for a nonlinear shell model

A nonlinear shell model is considered in this talk. This is a nonlinear variant of the Budiansky-Sanders linear shell model. Under some suitable assumptions on the magnitude of the applied force, we will prove the existence of a minimizer for this shell model. In addition, we will also show that our existence result can be applied to all kinds of geometries of the middle surface of the shell. We will also show that the minimiser found in this fashion is unique, provided the applied forces are small enough. Our result hence extends the one given by Destuynder in 1980s.

Zhen Hao

The Chinese University of Hong Kong

Asymptotic-Preserving Schemes for Boltzmann Mixture Models with Disparate Masses

Simulating gas mixtures with particles of vastly different masses is computationally challenging due to the disparity in their thermal velocities. In this talk, we introduce an asymptotic-preserving numerical scheme for the Boltzmann mixture model that efficiently handles large mass ratios. By employing asymptotic expansions for the collision operators and accounting for the multiple time scales in the relaxation process, our method captures the essential dynamics, including the epochal relaxation phenomenon. Numerical results validate the scheme's effectiveness and asymptotic properties, offering a powerful tool for studying multi-scale gas mixture systems.