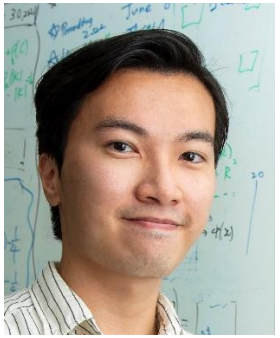
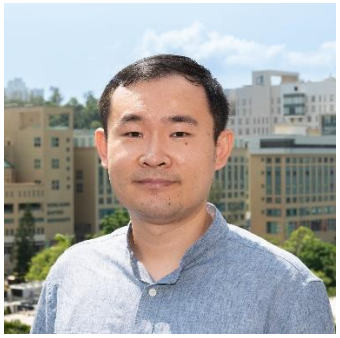
Project Abstracts for PhD Student Recruitment AY2025/26

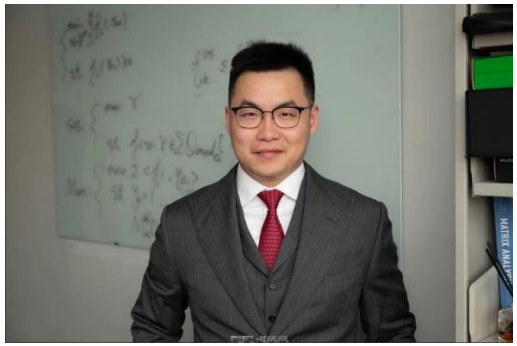
Department of Mathematics

Project title	**Statistical learning by structured neural networks**	
Research Clusters	☐Creative Media/Practice ☐ Health and Drug Discovery **√ Data Analytics and Artificial Intelligence in X** ☐ Humanities and Cultures	 ***Dr FAN Jun*** *Email address:* *junfan@hkbu.edu.hk* *Learn more:* *https://www.math.hkbu.edu.hk/~junfan/*
Keywords	*Statistical machine learning, deep learning theory, structured neural networks, optimization, high-dimensional data analysis*	
Project abstract	This project explores statistical learning through the lens of structured neural networks, aiming to enhance model interpretability and performance. By integrating principles from statistical theory and neural network design, we will investigate how structured architectures can effectively capture complex data patterns while maintaining computational efficiency. The research will focus on developing novel algorithms that leverage these structures for improved learning outcomes in various applications. Ultimately, this project seeks to advance our understanding of the interplay between statistical learning and neural network architecture, paving the way for more robust and interpretable AI systems.	

Project title	Optimal Preconditioning for Structured Systems with Applications to PDE Problems	
Keywords	*Toeplitz systems, circulant matrices, Tau matrices, preconditioning, MINRES*	
Project abstract	This project focuses on developing optimal preconditioning strategies for structured systems, particularly those arising in partial differential equations (PDEs). Preconditioning improves the efficiency of iterative solvers, particularly for large-scale systems encountered in scientific computing. By leveraging the specific structure of PDE problems, we aim to design preconditioners that enhance convergence rates while reducing computational costs. Applications in image processing, optimal pricing, optimal control problems, and other areas will be explored, demonstrating improved performance across a range of complex, real-world simulations.	 ***Dr Sean Y S HON*** *Email address:* *seanyshon@hkbu.edu.hk* *Learn more:* *https://sites.google.com/view/hkbu-seanyshon/about*

Project title	Mathematical models and analysis of a poroelastic approach for stimulus-responsive smart hydrogels	
Research Clusters	☐ Creative Media/Practice **√ Health and Drug Discovery** ☐ Data Analytics and Artificial Intelligence in X ☐ Humanities and Cultures	
Keywords	*Mathematical modelling, PDE analysis, Hydrogels, Poroelastic material, Long time behavior*	
Project abstract	Hydrogels are networks of polymer chains with the ability to absorb and hold large amounts of water. They have traditionally appeared in commercial hygiene and medical products, such as contact lenses and sanitary pads, as well as in biomedical applications like tissue engineering and wound healing. In recent years, they have become one of the next-generation smart materials and are sensitive to environmental changes and can alter their structures accordingly. We plan to develop new mathematical models for stimulus-responsive smart hydrogels. Then, we perform a rigorous mathematical analysis on the solvability of the new models and explore their equilibrium states.	 ***Dr LAM Kei Fong*** *Email address:* *akflam@hkbu.edu.hk* *Learn more:* *https://andrewkflam.github.io/*

Project title	Mathematical Model Guided Deep Learning Methods for Image Processing	
Research Clusters	☐ Creative Media/Practice ☐ Health and Drug Discovery **√ Data Analytics and Artificial Intelligence in X** ☐ Humanities and Cultures	 ***Dr LIU Hao*** *Email address:* *haoliu@hkbu.edu.hk* *Learn more:* *https://www.math.hkbu.edu.hk/~haoliu/*
Keywords	*Deep neural networks, mathematical models, image processing, operator-splitting methods*	
Project abstract	Deep neural networks have demonstrated great successes in image processing. However, a lot of network architectures are empirically designed. Mathematical explanations of their successes are missing. We will incorporate deep neural network with mathematical models to design new deep learning methods with mathematical explanations. We expect that our methods will leverage the strengths of both deep learning methods and mathematical models, and outperform existing state-of-the-art methods.	

Project title	Sparse polynomial optimization and its applications	
Keywords	*Polynomial optimization, sparsity, Moment-SOS relaxations, tight relaxation, Nash equilibrium*	
Project abstract	In this project, we investigate the theory and applications of sparse polynomial optimization, which are optimization problems given by polynomial functions which only have a small subset of variables. We mainly concern the tightness for the sparse Moment-SOS hierarchy of semidefinite relaxations for solving sparse polynomial optimization problems. Besides that, we are interested in applying related tools to solve difficult problems given by sparse polynomials, such as sparse Nash equilibrium problems of polynomials.	 ***Dr TANG Xindong*** *Email address:* *xdtang@hkbu.edu.hk* *Learn more:* *https://www.math.hkbu.edu.hk/~xdtang/*

Project title	Asymmetric classification and its extensions	
Research Clusters	☐ Creative Media/Practice ☐ Health and Drug Discovery **√ Data Analytics and Artificial Intelligence in X** ☐ Humanities and Cultures	
Keywords	*asymmetric classification, statistical learning*	
Project abstract	Classification is a widely employed technique in various fields, with traditional binary classification methods focusing on minimizing the combined rates of Type I errors (false positives) and Type II errors (false negatives). However, the relative importance of these errors often varies depending on the specific application. Consequently, there is a growing need for asymmetric control mechanisms that address the differing significance of Type I and Type II errors, allowing for more tailored and effective classification outcomes. This study will focus on the methodological advancements of asymmetric classification, derive its statistical properties, and explore its real-world applications. Moreover, I will conduct research on combining asymmetric classification with other statistics framework and techniques to address more specialized areas and enhance overall performance.	

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