应用数学前沿研讨会

Frontier Workshop in Applied Mathematics

https://www.gbu.edu.cn/detail/article/422

June 11 - June 13, 2023

Great Bay University

Dongguan, China

Web: www.gbu.edu.cn

Email: sciences@gbu.edu.cn

1. Notes

This Frontier workshop focuses on dynamical systems, including nonlinear dynamics, stochastic dynamics, quantum dynamics, biological dynamics, climate dynamics, and data-driven/machine learning for dynamical systems.

This workshop will celebrate Juergen Kurths’ scientific achievements on the occasion of his 70th birthday.

Workshop Date：June 11- June 13, 2023

Workshop Place：中国东莞，大湾区大学 Great Bay University, Dongguan, China

Scientific Committee:

Jinqiao Duan (Chair), Great Bay University, China

Guanrong Chen, City University of Hong Kong, China

Xiaopeng Chen, Shantou University, China

Organizers:

Ting Gao(co-Chair), Huazhong University of Science and Technology, China

Yayun Zheng(co-Chair), Jiangsu University, China

Fadi Sun, Great Bay University, China

Hui Wang, Zhengzhou University, China

Wei Zou, South China Normal University, China

2. Program

Place：Room1919, F19, Building A5, Songshan Lake International Innovation and Entrepreneurship Community, Great Bay University, Dongguan, Guangdong, China.

Zoom ID：815 3671 9960 Password：465074

Date：Sunday, June 11

Time	Program
Chair: Ting Gao	
9:30-9:50	Sign in
9:50-10:00	Jinqiao Duan(Great Bay University, China)
10:00-10:30	Jinzhi Lei（Tiangong University, China） Dynamics of cell type transition mediated by epigenetic modifications
10:30-11:00	Rui Liu（South China University of Technology, China） Alerting for the critical transition of complex systems: a high-throughput data-driven study
11:00-11:30	Quanying Liu（Southern University of Science and Technology, China） Controlling networked neural dynamics: system identification and optimal
Break	
Chair: Jinzhi Lei	
13:45-14:00	Opening

	Guanrong Chen(City University of Hong Kong, China) Jinqiao Duan(Great Bay University, China)
14:00-14:30	Juergen Kurths（Potsdam Institute for Climate Impact Research (PIK), Germany） Stability of power grids under strong perturbations
14:30-15:00	Heinz Koeppl （ The Technical University of Darmstadt, Germany）
15:00-17:00	Free discussion

Date：Monday, June 12

Time	**Program**
Chair: Jinqiao Duan	
9:40-10:00	Sign in
10:00-10:30	Wei Lin（Fudan University, China） Predicting and modulating complex dynamics using data-driven and machine learning techniques
10:30-11:00	Liang Huang（Lanzhou University, China） Quantum-Classical Correspondence of Finite-time Dynamics
11:00-11:30	Chen Jia（Beijing Computational Science Research Center, China） Mathematical theory for stochastic cell size dynamics
Break	

Chair: Yayun Zheng	
14:30-15:00	Christian Franzke（Pusan National University， Center for Climate Physics, Institute for Basic Science, South Korea） Causality Detection and Multi-Scale Decomposition of the Climate System using Machine Learning
15:00-15:30	Jordi Garcia Ojalvo（Department of Medicine and Life Sciences, Universitat Pompeu Fabra, Barcelona, Spain ） An integrate-and-fire mechanism of information processing in dormant cells
15:30-16:00	George Haller（ETH Zurich, Switzerland） Nonlinear Reduced-Order Modelling from Data
16:00-16:30	Valerio Lucarini（Department of Mathematics and Statistics, University of Reading, UK）
16:30-17:00	Niklas Boers（Potsdam Institute for Climate Impact Research, Germany） Critical Transitions in the Earth System

Date：Tuesday, June 13

Time	**Program**
9:30-11:30	Free discussion
Chair: Xiaopeng Chen	
13:40-14:00	Sign in

14:00-14:30	Hao Wu（Tongji University, China） 多体系统运动学降阶的机器学习方法
14:30-15:00	Yi Gao（Shenzhen University, China） Image computing---Algorithm, Tooling, and Practice
15:00-15:30	Stefan Klus（Heriot-Watt University, UK） Data-Driven Modeling of Dynamical Systems
Break	
16:15-16:45	Larissa Serdukova（University of Leicester,UK） L\'evy-noise versus Gaussian-noise-induced Transitions in the Ghil-Sellers Energy Balance Model
16:45-17:15	Closing Jinqiao Duan(Great Bay University, China)

3. Abstract

(1) **Speaker: Jinzhi Lei, School of Mathematical Sciences, Center for Applied Mathematics, Tiangong University.**

Title: Dynamics of cell type transition mediated by epigenetic modifications

Abstract: Maintaining tissue homeostasis requires proper regulation of stem cell differentiation. The Waddington landscape suggests that gene circuits in a cell form a potential landscape of different cell types, with cells developing into different cell types following attractors of the probability

landscape. However, it remains unclear how adult stem cells balance the trade-off between self-renewal and differentiation. We propose that random inheritance of epigenetic states plays a crucial role in stem cell differentiation and develop a hybrid model of stem cell differentiation induced by epigenetic modifications. Our model integrates a gene regulation network, epigenetic state inheritance, and cell regeneration to form multi-scale dynamics ranging from transcription regulation to cell population. Our simulation investigates how random inheritance of epigenetic states during cell division can automatically induce cell differentiation, dedifferentiation, and transdifferentiation. We show that interfering with epigenetic modifications or introducing extra transcription factors can regulate the probabilities of dedifferentiation and transdifferentiation, revealing the mechanism of cell reprogramming. This in silico model offers insights into the mechanism of stem cell differentiation and cell reprogramming.

(2) Speaker: Rui Liu, School of Mathematics, South China University of Technology

Title: Alerting for the critical transition of complex systems: a high-throughput data-driven study

Abstract: It is a challenging task to accurately predict the future critical state of a short-term time-series. The major difficulty to solve such a task is the lack of the information, which typically results in the failure of most existing approaches due to the overfitting problem of the small sample size. To address this issue, we proposed a computing framework: auto-reservoir neural network (ARNN), to efficiently and accurately make the multi-step-ahead prediction based on a short-term high-dimensional time-series. Different from traditional reservoir computing whose reservoir is an external dynamical system irrelevant to the target system, ARNN directly transforms the observed high-dimensional dynamics as its reservoir, which maps the high-dimensional/spatial data to the future temporal values of a target variable based on a spatiotemporal information (STI) transformation. The application in predicting the tipping points of complex systems will also be referred in this talk.

(3) **Speaker:Quanying Liu（Southern University of Science and Technology, China）**

Title: Controlling networked neural dynamics: system identification and optimal

Abstract: The brain is a complex network of interlinked regions that coordinate to integrate information from the environment and drive diverse behaviors. Modelling the networked neural dynamics and understanding the information flow across brain regions are essential for controlling neural states and behavior. In this talk, I will present a data-driven framework called Neural Perturbational Inference (NPI). It learns the brain network dynamics with an artificial neural network as a surrogate brain, and then to infer the whole-brain causal relationship by virtual perturbation. Then, I will introduce a model-based control framework for optimizing the neurostimulation policy to steer the abnormal brain state to the healthy state. It combines a dynamical model and a model predictive controller for the closed-loop neurostimulation.

(4) Speaker: Juergen Kurths （Potsdam Institute for Climate Impact Research (PIK), Germany）

Title: Stability of power grids under strong perturbations

(5) Speaker: Wei Lin, Fudan University, China

Title: Predicting and modulating complex dynamics using data-driven and machine learning techniques

Abstract: In the era of the data science, model-free techniques are developed overwhelmingly. When the experimentally-collected data are generated by dynamical systems, the missions of reconstruction, prediction, and modulation only based on these data are highly anticipated to be achieved for these systems. Here, we introduce several directions of progresses made by our research group in developing the model-free techniques using machine learning techniques and dynamical systems theory. We use representative systems of physical or/and biological significance to demonstrate the developed techniques. We hope that all the methods can shed a light on deciphering and controlling the hidden dynamics that dominate the evolutions of any systems in real-world.

(6) Speaker: Liang Huang, Lanzhou University

Title: Quantum-Classical Correspondence of Finite-time Dynamics

Abstract: Conventional quantum-classical correspondence is based on two assumptions: 1) the quantum system is in the semiclassical regime; 2) The quantum Heisenberg time is much longer than the time when classical dynamics reaches steady state. When any of these two conditions is broken, such as when the system cannot reach steady state and is thus intrinsically transient, or finite time dynamics are important characteristics of the system itself, or in deep quantum regions, the correspondence between the energy spectrum statistics and wave function characteristics of the quantum systems and the classical dynamics fails. Then is there still any correspondence, especially for systems with an intermediate degree of ergodicity? This talk will report our progress on this issue.

(7) Speaker: Chen Jia, Beijing Computational Science Research Center

Title: Mathematical theory for stochastic cell size dynamics

Abstract: Advances in microscopy enable us to follow single cells over long timescales from which we can understand how their size varies with time and the nature of innate strategies developed to control cell size. These data show that in many cell types, growth is exponential and the distribution of cell size has one peak, namely there is a single characteristic cell size. However data for fission yeast show remarkable differences: growth is non-exponential and the distribution of cell sizes has two peaks, corresponding to different growth phases. Here we construct a unified stochastic model of cell size dynamics in many cell types; by solving the cell size distribution analytically, we show that it is able to predict the unimodal distributions of cell size observed in exponentially growing cells and the bimodal distributions observed in non-exponentially growing cells. Furthermore, by fitting the model to the data, we infer values for the rates of all microscopic processes in our model. This method is shown to provide a much more reliable inference than conventional methods and shed light on how the strategy used by E. coli and fission yeast cells to control their size varies with external conditions. More importantly, we find that stronger size homeostasis and larger added size variability are required for fission yeast to adapt to unfavorable environmental conditions.

(8) Speaker:Christian Franzke, Pusan National University,Center for Climate Physics, Institute for Basic Science, South Korea

Title: Causality Detection and Multi-Scale Decomposition of the Climate

System using Machine Learning

Abstract: Detecting causal relationships and physically meaningful patterns from the complex climate system is an important but challenging problem. In my presentation I will show recent progress for both problems using Machine Learning approaches. First, I will show that Reservoir Computing is able to systematically identify causal relationships between variables. I will show evidence that Reservoir Computing is able to systematically identify the causal direction, coupling delay, and causal chain relations from time series. Reservoir Computing Causality has three advantages: (i) robustness to noisy time series; (ii) computational efficiency; and (iii) seamless causal inference from high-dimensional data. Second, I will demonstrate that Multi-Resolution Dynamic Mode Decomposition can systematically identify physically meaningful patterns in high-dimensional climate data. In particular, Multi-resolution Dynamic Mode Decomposition is able to extract the changing annual cycle.

(9) **Speaker: Jordi Garcia-Ojalvo, Department of Medicine and Life Sciences, University Pompeu Fabra, Barcelona**

Title: An integrate-and-fire mechanism of information processing in dormant cells

Abstract: Cells are nonlinear dynamical systems that process time-dependent signals coming from their environment. Studying how such

information processing comes about is a complicated task, due to the difficulty of uncoupling the intrinsic dynamical character of cells with the dynamics of the environment. In this talk I will consider a special type of ultra-dormant cells with a very simple internal state, namely bacterial spores, and discuss how these cells monitor their environment in the presence of periodic trains of nutrients. Our results show that spores use an integrate-and-fire mechanism, analogous to that employed by neurons, to decide when to germinate. The model is validated by genetic and chemical perturbations, both in silico and in vivo.

(10) Speaker: George Haller, ETH Zurich, Switzerland

Title: Nonlinear Reduced-Order Modelling from Data

Abstract: A reduced-order modelling of very large, nonlinear systems remains a major challenge despite advances in computational power. Projection-based model reduction techniques have been in use for this purpose but they rely on ad hoc mode selection and produce a priori unknown errors. In this talk, I discuss a recent mathematical alternative to these approaches based on spectral submanifolds (SSMs), which are very low dimensional, attracting invariant surfaces in nonlinear systems. Reduction to SSMs turns out to yield previously unimaginable speed-ups in solving large finite-element models. Very recent results also show that SSMs and their reduced dynamics can be constructed directly from data. I

will illustrate these results on numerical and experimental flow data sets.

(11) Speaker: Niklas Boers, Potsdam Institute for Climate Impact Research, Germany

Title: Critical Transitions in the Earth System

Abstract: In response to anthropogenic release of greenhouse gases, the Earth is warming at unprecedented rates. It has been suggested that several components of the Earth's climate system may respond with abrupt transitions between alternative stable states in response to anthropogenic climate change. Based on the theory of stochastically forced dynamical systems and their bifurcations, a methodology is presented to measure changes in the stability of a given equilibrium state from observational time series. The method is applied to observation-based data to investigate stability changes of the Greenland Ice Sheets, the Atlantic Meridional Overturning Circulation, and global ecosystems with focus on the Amazon rainforest.

(12) Speaker: Hao Wu, Tongji University

Title: 多体系统运动学降阶的机器学习方法

Abstract:以分子动力学为代表的多体系统模拟技术在科学与工程的各个领域中扮演着重要的角色。随着高性能计算、云计算以及大规模模拟算法的不断进步，多体系统模拟已经能够涵盖更大的系统空间尺度和维

度。在这一发展趋势下，如何利用模拟数据对高维多体系统的运动学进行有效降维，并在此基础上进行进一步的分析与建模，成为了一个具有挑战性的问题。在本次报告中，我们将从马尔可夫过程的角度出发，介绍我们在基于转移算子理论和信息论的反应坐标辨识及模型降阶方面的工作。特别地，我们将重点介绍深度学习技术在相关研究中所发挥的重要作用。

(13) Speaker: Yi Gao, Shenzhen University, China

Title: Image computing---Algorithm, Tooling, and Practice

Abstract: In this talk he will be discussing various projects on medical image computing. In particular, the usage of a combined machine learning and geometric prior framework for the detection, extraction, and analysis of medical image data. He will also be talking about the translation or research where the algorithms are implemented as user friendly open source software, which would be beneficial for the entire community. Furthermore, utilizing the algorithms and software infrastructure he built through the years, he will talk about the project of breast cancer screening throughout the country.

(14) Speaker: Stefan Klus, Heriot-Watt University, UK

Title: Data-Driven Modeling of Dynamical Systems

Abstract: Many dimensionality and model reduction techniques rely on estimating dominant eigenfunctions of associated dynamical operators from data. Important examples include the Koopman operator and its generator, but also the Schrödinger operator. We will present kernel-based methods for the approximation of transfer operators and differential operators in reproducing kernel Hilbert spaces and show how eigenfunctions can be estimated by solving auxiliary matrix eigenvalue problems. We will illustrate the results with the aid of guiding examples and highlight potential applications in molecular dynamics, fluid dynamics, and quantum mechanics. Furthermore, we will exploit relationships between the graph Laplacian and transfer operators and in particular between clusters in undirected graphs and metastable sets and then use a generalization of the notion of metastability to derive clustering algorithms for directed and time-evolving graphs.

(15) **Speaker: Larissa Serdukova, Department of Computing and Mathematical Sciences, University of Leicester, UK**

Title: L\'evy-noise versus Gaussian-noise-induced Transitions in the Ghil-Sellers Energy Balance Model

Abstract: We study the impact of applying stochastic forcing to the Ghil-Sellers energy balance climate model in the form of a fluctuating solar irradiance. Through numerical simulations, we explore the noise-induced transitions between the competing warm and snowball climate states. We consider multiplicative stochastic forcing driven by Gaussian and

α-stable L\'evy - $\alpha\in(0,2)$ - noise laws, examine the statistics of transition times, and estimate the most probable transition paths. While the Gaussian noise case - used here as a reference - has been carefully studied in a plethora of investigations on metastable systems, much less is known about the L\'evy case, both in terms of mathematical theory and heuristics, especially in the case of high- and infinite-dimensional systems. In the weak noise limit, the expected residence time in each metastable state scales in a fundamentally different way in the Gaussian vs. L\'evy noise case with respect to the intensity of the noise. In the former case, the classical Kramers-like exponential law is recovered. In the latter case, power laws are found, with the exponent equal to $-\alpha$, in apparent agreement with rigorous results obtained for additive noise in a related - yet different - reaction-diffusion equation as well as in simpler models. This can be better understood by treating the L\'evy noise as a compound Poisson process. The transition paths are studied in a projection of the state space and remarkable differences are observed between the two different types of noise. The snowball-to-warm and the warm-to-snowball most probable transition path cross at the single unstable edge state on the basin boundary. In the case of L\'evy noise, the most probable transition paths in the two directions are wholly separated, as transitions apparently take place via the closest basin boundary region to the outgoing attractor. This property can be better elucidated by considering singular perturbations to solar irradiance.

大湾区大学简介

粤港澳大湾区总面积5.6万平方公里。推进粤港澳大湾区建设，是以习近平同志为核心的党中央作出的重大决策，是习近平总书记亲自谋划、亲自部署、亲自推动的国家战略。

目前，粤港澳三地现有高校192所，每百万人口拥有的高校约2.64所，低于纽约湾区11.24所、旧金山湾区10.71所、东京湾区5.95所，显示粤港澳大湾区高等教育资源总量不足。东莞作为粤港澳大湾区建设的节点城市，办学层次和结构体系有待完善，高等教育综合实力有待提高——大湾区大学应运而生。筹建大湾区大学是贯彻《粤港澳大湾区发展规划》的重大战略举措。大湾区大学是由广东省人民政府举办、东莞市政府投入保障为主的公办普通高等学校。

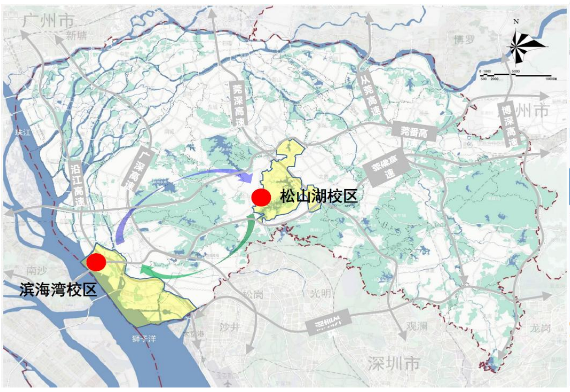
大湾区大学定位为新型研究型大学，以理工科为主，兼有管理学科；在本科、硕士、博士多层次上办学，立足东莞、服务广东、面向全国、放眼世界。旨在办成一所独具特色的、引领未来科技发展、产业升级和社会进步的世界一流大学。

在办学定位方面，以理工科为主，突出人才培养模式创新，致力于培养适应未来快速变化、支撑和引领大湾区科创发展的高端人才，产出一流成果，服务于提升大湾区科创竞争力和打造国际一流湾区，办成一所独具特色、引领未来科技发展、产业升级和社会进步的新型研究型大学。

在办学特色方面，围绕"深度协同合作育人、创新教学组织架构、实施跨学科项目式教学、建立多元化考核体系"等特色开展办学，并通过构

建外引内育，专聘结合的师资引进机制，着重招聘国内外卓越科研人才。

在办学规模方面，大湾区大学提供全日制学士、硕士和博士学位课程。到 2030 年，预计招生约 1 万人，本科生与研究生比例将达到 1:1 左右。在校园建设方面，按照“一校两区”的思路在东莞滨海湾新区和松山湖高新区规划建设，总占地约 2356 亩；其中，松山湖校区 256 亩，滨海湾校区 2100 亩。



Great Bay University Introduction

Great Bay University is a research-based university with distinctive characteristics that will lead the industrial upgrading, technological development, and social progress. Giving priority to science and engineering subjects and creative talents training, the university aims to cultivate high-end talents that can adapt to the rapid changes in the future and lead the development of science and technologies in the Greater Bay Area. In the meanwhile, it also aims to bring top-flight outcomes, serving to enhance regional competitiveness and build a world-class area.

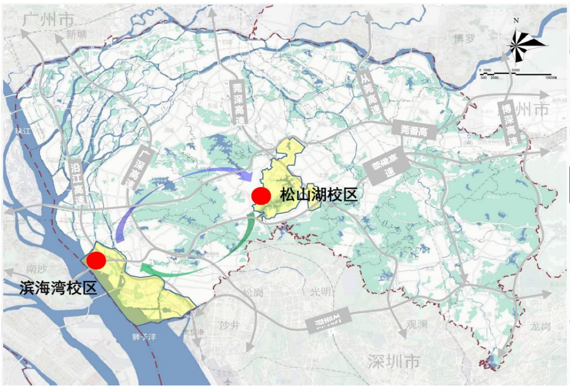
Great Bay University provides full-time programs for bachelor, master and PhD degrees. By 2030, it is expected to have enrolled about 10,000 students, and the ratio of undergraduates to graduate students will reach about 1:1.

In-depth collaborate and cultivate talents. While highlighting the fundamental research and education of science and engineering subjects, make full use of the massive scientific facilities such as the Spallation Neutron Source, Songshan Lake Material Laboratory, etc., new-type research and development institutions, and other leading technology enterprises, establish a “cooperation community of science, education, and industry” in the way of “University + Massive Scientific Facilities (R&D institutions included) + Leading Science and Technology Enterprises”, focus on promoting the “six joints” (i.e. jointly development plans, curriculum setup, talent pool, joint laboratory, student evaluation, and entrepreneurial and vocational guidance), and build a whole-process cooperation chain involving personnel training, fundamental research, and achievements transformation.

Innovate teaching organization structure. The university will adopt flattening management and flexible teaching modes, realize the sharing of education and scientific research resources, concentrate on the development of integration and innovative research of cutting-edge technology, and focus on six directions including material science, advanced engineering, life science, new-generation information technology, science, and finance.

Implement interdisciplinary project-based teaching mode. The university will lay emphasis on the integrity of students' knowledge, encouraging students to tackle problems with interconnected and integrated knowledge or skills. Based on the real-world R&D projects and industrial projects provided to the students by the "cooperation community of science, education, and industry" provide, the mode will connect the entire learning process of students through practical teaching, build up a brand new curriculum from a knowledge system to a capability system, from a single structure to diversified integration, and from theoretical questions to actual scenarios. The dual-mentor team will guide students to actively learn relevant knowledge and cultivate their critical thinking abilities and design thinking from the process of solving actual problems.




广州市
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深圳市

大湾区大学
松山湖校区
莞台生物技术
合作育成中心
华为制造基地
中央创新区
华为终端基地
香港城市大学
（东莞）
松山湖材料实验室
科普公园
散裂中子源
南方光源研究测试平台

主办单位

大湾区大学，理学院

School of Sciences, Great Bay University