2025 TYMRC Workshop on Quantum Information and Optimization

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目录

Organizing Committee

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2025 TYMRC Workshop on Quantum Information and Optimization

Organization of the Program

Agenda

Time	Monday 4.14	Tuesday 4.15	Wednesday 4.16	Thursday 4.17	Friday 4.18
8:50-9:00	opening				
	Chair: Xin Wang	Chair: Jingsong Huang	Chair: Bin Gao	Chair: Yinan Li	Chair: Kun Fang
9:00 –10:00	Jingsong Huang	Shi Jin	Yingzhou Li	Li Gao	Penghui Yao
			Jie Wang	Zhengjun Xi	
10:00-10:30	Coffee Break	Group Photo	Coffee Break		
10:30-11:00	Dong An	Haidong Yuan	Tianyu Wang	Bujiao Wu	Yadong Wu
11:00-11:30	Jinguo Liu	Ge Bai	Ruchi Guo	Kun Fang	Lingling Lao
11:30-12:00	Yuxiang Yang	Naixu Guo	Yinan Li	Zhijian Lai	Xuanqiang Zhao
12:00-14:30	Lunch				
	Chair: Shi Jin	Chair: Yun Shang	Excursion	Chair: Li Gao	Free Discussion
14:30-15:00	Huangjun Zhu	Yuling Jiao		Minbo Gao	
15:00-15:30				Zhan Yu	
15:30-16:00	Coffee Break	Coffee Break		Coffee Break	
16:00-16:30	Changpeng Shao	Panel: Quantum & Opt		Open Problem Session	
16:30-17:00	Yu-Ao Chen				
17:00-19:00	Dinner				

Workshop Schedule

日期	时间	报告信息	
0414 -周一	09:00-10:00	主持人：王鑫	报告人：黄劲松 题目：Invariant Theory in Quantum Computing
	10:00-10:30		茶歇
	10:30-11:00		报告人：安冬 题目：Quantum algorithms for linear differential equations
	11:00-11:30		报告人：刘金国 题目：Automated Discovery of Branching Rules with Optimal Complexity for the Maximum Independent Set Problem
	11:30-12:00		报告人：杨宇翔 题目：Fully-optimized quantum metrology
	12:00-14:30	午餐	
	14:30-15:30	主持人：金石	报告人：朱黄俊 题目：Nonstabilizerness Enhances Thrifty Shadow Estimation
	15:30-16:00		茶歇
	16:00-16:30		报告人：邵长鹏 题目：Randomized quantum singular value transformation
	16:30-17:00		报告人：陈俣翱 题目：Optimal Quantum Hypothesis Testing of Unitary Distributions

<table>
<tr><td rowspan="10">0415 -周二</td><td>09:00-10:00</td><td rowspan="5">主持人：黄劲松</td><td>报告人：金石
题 目 ：Dimension Lifting for Quantum Computation of partial differential equations and related problems</td></tr>
<tr><td>10:00-10:30</td><td>合照，茶歇</td></tr>
<tr><td>10:30-11:00</td><td>报告人：袁海东
题目：Incompatibility measures in multi-parameter quantum estimation under hierarchical quantum measurements</td></tr>
<tr><td>11:00-11:30</td><td>报告人：柏舸
题目：Quantum Bayes' rule and Petz transpose map from the minimum change principle</td></tr>
<tr><td>11:30-12:00</td><td>报告人：郭乃绪
题目：Design nearly optimal quantum algorithm for linear differential equations via Lindbladians</td></tr>
<tr><td>12:00-14:30</td><td colspan="2">午餐</td></tr>
<tr><td>14:30-15:30</td><td rowspan="3">主持人：尚云</td><td>报告人：焦雨领
题目： DRM Revisited: A Complete Error Analysis</td></tr>
<tr><td>15:30-16:00</td><td>茶歇</td></tr>
<tr><td>16:00-17:00</td><td>圆桌讨论: Quantum and Optimization</td></tr>
</table>

0416 -周三	09:00-10:00	主持人：高斌	报告人：李颖洲 题目：Quantum Circuit for Non-Unitary Linear Transformation of Basis Sets
			报告人：王杰 题目：State Polynomial Optimization and Nonlinear Bell Inequalities
	10:00-10:30		茶歇
	10:30-11:00		报告人：王天宇 题目：Convex Optimization over Alexandrov Spaces: A Quasi-linearization Approach
	11:00-11:30		报告人：郭汝驰 题目：Optimization and preconditioning: TPDv algorithms for nonlinear PDEs
	11:30-12:00		报告人：李绎楠 题目：Rigorous QROM Security Proofs for Some Post-Quantum Signature Schemes Based on Group Actions
	12:00-14:30	午餐	
	14:30-17:00	Excursion	

	09:00-10:00	主持人：李绎楠	报告人：高力 题目：Convex Splitting: tight analysis and multipartite case
			报告人：席政军 题目：量子资源对多用户安全通信的优化作用
	10:00-10:30		茶歇
	10:30-11:00		报告人：吴步娇 题目：Linear properties of quantum states
	11:00-11:30		报告人：方堃 题目：Generalized quantum asymptotic equipartition
	11:30-12:00		报告人：赖志坚 题目：Optimal Interpolation-based Coordinate Descent Method for Variational Quantum Algorithms
0417 -周四	12:00-14:30	午餐	
	14:30-15:00	主持人：高力	报告人：高敏博 题目：量子近似 k 最小值查找
	15:00-15:30		报告人：余展 题目：Quantum signal processing in machine learning and algorithm design
	15:30-16:00		茶歇
	16:00-17:00		Open Problem Session

0418 -周五	09:00-10:00	主持人：方堃	报告人：姚鹏晖 题目：Some Applications of Pauli analysis on Quantum Algorithms and Complexity
	10:00-10:30		茶歇
	10:30-11:00		报告人：吴亚东 题目：神经网络学习量子系统
	11:00-11:30		报告人：劳玲玲 题目：Decoding algorithms for surface codes
	11:30-12:00		报告人：赵炫强 题目：Advantages of indefinite causal order in communication
	12:00-14:30	午餐	
	14:30-17:00	Free Discussion	

Titles and Abstracts

09:00-10:00, Apr. 14, Monday Speaker: Jingsong Huang

Title: Invariant Theory in Quantum Computing

Abstract: Algebraic and geometric invariants have been extensively studied in algebra and geometry. Both classical invariant theory and geometric invariant theory play important roles in the current development of representation theory and algebraic geometry. In this talk, we discuss application of the invariant theory to implementation of the quantum Fourier transform and measurement of the quantum entanglement.

10:30-11:00, Apr. 14, Monday Speaker: Dong An

Title: Quantum algorithms for linear differential equations

Abstract: Designing quantum algorithms for solving linear differential equations has attracted great attention due to its potential exponential speedup over classical algorithms and its fundamental role in scientific and engineering computation. In this talk, we will discuss how to design a generic quantum linear differential equation algorithm with near-optimal complexity in all parameters. The idea of the algorithm is based on the linear combination of Hamiltonian simulation technique. In addition, for dissipative differential equations, we will discuss a fast-forwarded quantum algorithm with further improved time complexity.

11:00-11:30, Apr. 14, Monday Speaker: Jinguo Liu

Title: Automated Discovery of Branching Rules with Optimal Complexity for the Maximum Independent Set Problem

Abstract: The branching algorithm is a fundamental technique for designing fast exponential-time algorithms to solve combinatorial optimization problems exactly. It divides the entire solution space into independent search branches using predetermined branching rules, and ignores the search on suboptimal branches to reduce the time complexity. The complexity of a branching algorithm is primarily determined by the branching rules it employs, which are often designed by human experts. In this paper, we show how to automate this process with a focus on the maximum independent set problem. The main contribution is an algorithm that efficiently generates optimal branching rules for a given sub-graph with tens of vertices. Its efficiency enables us to generate the branching rules on-the-fly, which is provably optimal and significantly reduces the number of branches compared to existing methods that rely on expert-designed branching rules. Numerical experiments on 3-regular graphs shows an average complexity of O(1.0441^n) can be achieved, better than any previous methods.

11:30-12:00, Apr. 14, Monday Speaker: Yuxiang Yang

Title: Fully-optimized quantum metrology

Abstract: One of the main quests in quantum metrology is to attain the ultimate precision limit with given resources, where the resources are not only of the number of queries, but more importantly of the allowed strategies. With the same number of queries, the restrictions on the strategies constrain the achievable precision. In this talk, I will introduce a systematic framework to identify the ultimate precision limit of different families of strategies, including the parallel, the sequential and the indefinite-causal order strategies, and provide an efficient algorithm that determines an optimal strategy within the family of strategies under consideration. With this framework, we can show there exists a strict hierarchy of the precision limits for different families of strategies.

14:30-15:30, Apr. 14, Monday Speaker: Huangjun Zhu

Title: Nonstabilizerness Enhances Thrifty Shadow Estimation

Abstract: Shadow estimation is a powerful approach for estimating the expectation values of many observables. Thrifty shadow estimation is a simple variant that is proposed to reduce the experimental overhead by reusing random circuits repeatedly. Although this idea is so simple, its performance is quite elusive. In this work we show that thrifty shadow estimation is effective on average whenever the unitary ensemble forms a 2-design, in sharp contrast with the previous expectation. In thrifty shadow estimation based on the Clifford group, the variance is inversely correlated with the degree of nonstabilizerness of the state and observable, which is a key resource in quantum information processing. For fidelity estimation, it decreases exponentially with the stabilizer 2-Rényi entropy of the target state, which endows the stabilizer 2-Rényi entropy with a clear operational meaning. In addition,we propose a simple circuit to enhance the efficiency, which requires only one layer of T gates and is particularly appealing in the NISQ era.

16:00-16:30, Apr. 14, Monday Speaker: Changpeng Shao

Title: Randomized quantum singular value transformation

Abstract: In this talk, I will introduce a recent work with Shantanav Chakraborty, Soumyabrata Hazra, Tongyang Li, Xinzhao Wang and Yuxin Zhang (arXiv:2504.02385). The talk is about implementing quantum singular value transformation without block-encoding, assuming the input matrix is given as a linear combination of unitaries. We propose algorithms achieving near optimal complexity, meanwhile only use 1 ancilla qubit.

16:30-17:00, Apr. 14, Monday Speaker: Yu-Ao Chen

Title: Optimal Quantum Hypothesis Testing of Unitary Distributions

Abstract: Symmetry is fundamental in quantum physics, governing the behavior and dynamics of physical systems. We develop a hypothesis-testing framework for quantum dynamics symmetry based on querying an unknown unitary operation. Leveraging the symmetry properties of compact groups and their irreducible representations, we characterize the optimal type-II error in unitary subgroup hypothesis testing and demonstrate that parallel, adaptive, indefinite causal order, and general strategies are equally powerful in achieving this optimal error rate. Furthermore, we present a general solution for evaluating the optimal type-II error, which depends solely on the irreducible representations of the group and its subgroup. Applying our results to hypothesis testing of U(2) over the singleton group, maximal commutative group, and orthogonal group, we provide analytical and optimal characterizations of type-II error for predicting identity, Z-symmetry, and T-symmetry in unknown qubit unitary operations. Additionally, we extend our analysis to the hypothesis testing of the groups $\{R_x(t)\}$ and $\{R_z(t)\}$ within U(2), showing that adaptive and general strategies achieve the same optimal type-II error, with the adaptive strategy fitting within the quantum signal processing framework.

09:00-10:00, Apr. 15, Tuesday Speaker: Shi Jin

Title: Dimension Lifting for Quantum Computation of partial differential equations and related problems

Abstract: Quantum computers have the potential to gain algebraic and even up to exponential speed up compared with its classical counterparts, and can lead to technology revolution in the 21st century. Since quantum computers are designed based on quantum mechanics principle, they are most suitable to solve the Schrodinger equation, and linear PDEs (and ODEs) evolved by unitary operators. The most efficient quantum PDE solver is quantum simulation based on solving the Schrodinger equation. It will be interesting to explore what other problems in scientific computing, such as ODEs, PDEs, and linear algebra that arise in both classical and quantum systems, can be handled by quantum simulation.

We will present a systematic way to develop quantum simulation algorithms for general differential equations. Our basic framework is dimension lifting, that transfers nonlinear PDEs to linear ones, and linear ones to Schrodinger type PDEs. For non-autonomous PDEs and ODEs, or Hamiltonian systems with time-dependent Hamiltonians, we also add an extra dimension to transform them into autonomous PDEs that have only time-independent coefficients, thus quantum simulations can be done without using the cumbersome Dyson's series and time-ordering operators. Our formulation allows both qubit and qumode (continuous-variable) formulations, and their hybridizations, and provides the foundation for analog quantum computing.

10:30-11:00, Apr. 15, Tuesday Speaker: Haidong Yuan

Title: Incompatibility measures in multi-parameter quantum estimation under hierarchical quantum measurements

Abstract: The incompatibility of the optimal measurements for the estimation of different parameters constraints the achievable precisions in multi-parameter quantum estimation. Understanding the tradeoff induced by such incompatibility is thus a central topic in quantum metrology. Here we provide an approach to study the incompatibility in terms of information geometry. We demonstrate the power of the approach by present a hierarchy of analytical tradeoff relations induced by the incompatibility.

11:00-11:30, Apr. 15, Tuesday Speaker: Ge Bai

Title: Quantum Bayes' rule and Petz transpose map from the minimum change principle.

Abstract: Bayes' rule, which is routinely used to update beliefs based on new evidence, can be derived from a principle of minimum change. This principle states that updated beliefs must be consistent with new data, while deviating minimally from the prior belief. Here, we introduce a quantum analog of the minimum change principle and use it to derive a quantum Bayes' rule by minimizing the change between two quantum input-output processes, not just their marginals. This is analogous to the classical case, where Bayes' rule is obtained by minimizing several distances between the joint input-output distributions. When the change maximizes the fidelity, the quantum minimum change principle has a unique solution, and the resulting quantum Bayes' rule recovers the Petz transpose map in many cases.

11:30-12:00, Apr. 15, Tuesday Speaker: Naixu Guo

Title: Design nearly optimal quantum algorithm for linear differential equations via Lindbladians

Abstract: Solving linear ordinary differential equations (ODE) is one of the most promising applications for quantum computers to demonstrate exponential advantages. The challenge of designing a quantum ODE algorithm is how to embed non-unitary dynamics into intrinsically unitary quantum circuits. In this work, we propose a new quantum algorithm for ODEs by harnessing open quantum systems. Specifically, we utilize the natural non-unitary dynamics of Lindbladians with the aid of a new technique called the non-diagonal density matrix encoding to encode general linear ODEs into non-diagonal blocks of density matrices. This framework enables us to design a quantum algorithm that has both theoretical simplicity and good performance. Combined with the state-of-the-art quantum Lindbladian simulation algorithms, our algorithm, under a plausible input model, can outperform all existing quantum ODE algorithms and achieve near-optimal dependence on all parameters. We also give applications of our algorithm including the Gibbs state preparations and the partition function estimations.

14:30-15:30 Apr. 15, Tuesday Speaker: Yuling Jiao

Title: DRM Revisited: A Complete Error Analysis

Abstract: The error analysis of deep learning includes approximation error, statistical error, and optimization error. However, existing works often struggle to integrate these three types of errors due to overparameterization. In this talk, we aim to bridge this gap by addressing a key question in the analysis of the Deep Ritz Method (DRM): "Given a desired level of precision, how can we determine the number of training samples, the parameters of neural networks, the step size of gradient descent, and the number of iterations needed so that the output deep networks from gradient descent closely approximate the true solution of the PDEs with the specified precision?"

09:00-9:30, Apr. 16, Wednesday Speaker: Yingzhou Li

Title: Quantum Circuit for Non-Unitary Linear Transformation of Basis Sets

Abstract: This talk introduces a novel approach to implementing non-unitary linear transformations of basis on quantum computational platforms, a significant leap beyond the conventional unitary methods. By integrating Singular Value Decomposition (SVD) into the process, the method achieves an operational depth of O(n) with at most n ancilla qubits, enhancing the computational capabilities for analysing fermionic systems. By this trick, we can calculate two ansatzes' overlap which live in two different basis. This allows us to orthogonalize the ansatzes under different basis sets, which provides the opportunity to use ansatzes from different basis sets to calculate different energy eigenstates and improve the accuracy when computing the energies of multiple eigenstates simultaneously. This novel approach allows for a deeper exploration of complex quantum states and phenomena, expanding the practical applications of quantum computing in physics and chemistry.

9:30-10:00, Apr. 16, Wednesday Speaker: Jie Wang

Title: State Polynomial Optimization and Nonlinear Bell Inequalities

Abstract: State polynomials are polynomials in noncommuting variables and formal states of their products. We present a complete hierarchy of semidefinite relaxations for solving state polynomial optimization problems. This hierarchy can be seen as a state analog of the Navascues-Pironio-Acin scheme for optimization of noncommutative polynomials. The motivation behind this theory arises from the study of correlations in quantum networks. Determining the maximal quantum violation of a polynomial Bell inequality for an arbitrary network is reformulated as a state polynomial optimization problem.

10:30-11:00, Apr. 16, Wednesday Speaker: Tianyu Wang

Title: Convex Optimization over Alexandrov Spaces: A Quasi-linearization Approach

Abstract: We study convergence results for classis optimization problems over Hadamard manifolds, with the boundedness assumptions completely removed. Our result is achieved via quasi-linearization of the Alexandrov spaces.

11:00-11:30, Apr. 16, Wednesday Speaker: Ruchi Guo

Title: Optimization and preconditioning: TPDv algorithms for nonlinear PDEs

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. In this work, we introduce an efficient transformed primal-dual (TPD) algorithm to solve the aforementioned nonlinear saddle point problems.

11:30-12:00, Apr. 16, Wednesday Speaker: Yinan Li

Title: Rigorous QROM Security Proofs for Some Post-Quantum Signature Schemes Based on Group Actions

Abstract: Group action based cryptography was formally proposed in the seminal paper of Brassard and Yung (Crypto ’90) and recently further developed by Ji et al. (TCC ’19) and Alamati et al. (AsiaCrypt ’19). Three submissions to the NIST’s call for additional post-quantum digital signatures, such as ALTEQ and MEDS, are based on one-way group actions. One approach to proving the QROM security for these group action based schemes uses the perfect unique response property introduced by Unruh (Eurocrypt ’12; AsiaCrypt ’17). In the contexts of ALTEQ and MEDS, this means that a random element does not have a non-trivial automorphism. Before this work, only computational evidence for small dimensions (Bläser et al., PQCrypto ’24; Reijnders–SamardjiskaTrimoska, Des. Codes Cryptogr. ’24) or subexponential bounds (Li–Qiao, FOCS ’17) are known. In this work, we formally prove that the average order of stabilizer groups is asymptotically trivial. As a result, when the dimension is large enough, all but an exponentially small fraction of alternating trilinear forms or matrix codes have the trivial stabilizer, confirming the assumptions for alternating trilinear forms (ALTEQ) and matrix codes (MEDS). Our approach is to examine the fixed points of the induced action of an invertible matrix over a finite field on trilinear forms.

09:00-9:30, Apr. 17, Thursday Speaker: Li Gao

Title: Convex Splitting: tight analysis and multipartite case

Abstract: Convex splitting is a powerful tool in quantum information that has been used in many information-processing protocols such as quantum state redistribution and quantum channel coding. In this talk, we will present some near optimal one-shot estimates for convex splitting which yields matched second-order asymptotics as well as error and strong converse exponent. Moreover, using an interesting decomposition, our error exponent estimate also applies to multipartite case, which leads to the resolution of Quantum Broadcast Channel Simulation. This talk is based on joint works with Hao-Chung Cheng and Mario Berta.

09:30-10:00, Apr. 17, Thursday Speaker: Zhengjun Xi

Title: 量子资源对多用户安全通信的优化作用

Abstract: 如何利用量子资源（如量子纠缠、量子边信息等）提升多用户通信效率与通信安全性成为核心挑战。在本次报告中，将聚焦两类典型问题：一是具有互补量子边信息的相关信源编码，讨论两解码器分别持有不同量子系统作为边信息时，如何通过子空间投影与联合典型性编码实现信源的高效压缩，并推广至有损场景下的速率-失真权衡；二是纠缠辅助的经典-量子多接入信道的私密通信，研究两发送端与单接收端共享纠缠时经典信息的安全传输容量域。

10:30-11:00, Apr. 17, Thursday Speaker: Bujiao Wu

Title: Linear properties of quantum states

Abstract: Estimating properties of quantum states, such as fidelities, molecular energies, and correlation functions, is a central challenge in quantum information science. A key question is how to perform these estimations efficiently. This talk addresses this question by exploring research on randomized measurement techniques and related protocols for optimizing the expectation values of observables. Topics covered include: (1) classical shadows in qubit and fermionic systems, both with and without error mitigation, (2) randomized measurement schemes based on Pauli decomposition, and (3) algorithms leveraging quantum parameterized circuits for randomized measurements.

11:00-11:30, Apr. 17, Thursday Speaker: Kun Fang

Title: Generalized quantum asymptotic equipartition

Abstract: We establish a generalized quantum asymptotic equipartition property (AEP) beyond the i.i.d. framework where the random samples are drawn from two sets of quantum states. In particular, under suitable assumptions on the sets, we prove that all operationally relevant divergences converge to the quantum relative entropy between the sets. More specifically, both the smoothed min- and max-relative entropy approach the regularized relative entropy between the sets. Notably, the asymptotic limit has explicit convergence guarantees and can be efficiently estimated through convex optimization programs, despite the regularization, provided that the sets have efficient descriptions. We give four applications of this result: (i) The generalized AEP directly implies a new generalized quantum Stein's lemma for conducting quantum hypothesis testing between two sets of quantum states. (ii) We introduce a quantum version of adversarial hypothesis testing where the tester plays against an adversary who possesses internal quantum memory and controls the quantum device and show that the optimal error exponent is precisely characterized by a new notion of quantum channel divergence, named the minimum output channel divergence. (iii) We derive a relative entropy accumulation theorem stating that the smoothed min-relative entropy between two sequential processes of quantum channels can be lower bounded by the sum of the regularized minimum output channel divergences. (iv) We apply our generalized AEP to quantum resource theories and provide improved and efficient bounds for entanglement distillation, magic state distillation, and the entanglement cost of quantum states and channels. At a technical level, we establish new additivity and chain rule properties for the measured relative entropy which we expect will have more applications.

11:30-12:00, Apr. 17, Thursday Speaker: Zhijian Lai

Title: Optimal Interpolation-based Coordinate Descent Method for Variational Quantum Algorithms

Abstract: In this paper, we propose an optimal interpolation-based coordinate descent (OICD) method to solve the classical optimization problem that arises in variational quantum algorithms (VQAs). The OICD method reduces the cost burden on quantum devices by approximating the cost functions through interpolation method. Specifically, by using a trigonometric polynomial model to represent univariate constraint functions (i.e., involving only one tunable parameter), OICD efficiently captures the key information needed for optimization. A key aspect of the OICD method is the selection of appropriate interpolation points to minimize noise impact. To this end, we numerically determine the optimal interpolation points during the OICD's preparation phase. Remarkably, for the case of equidistant frequencies (where the Hermitian generator in quantum circuit is typically a Pauli word), we have theoretically proven that the optimal interpolation points are $\frac{2\pi}{n}$-equidistant points, and this scheme satisfies three different criteria simultaneously

14:30-15:00, Apr. 17, Thursday Speaker: Minbo Gao

Title: 量子近似 k 最小值查找

Abstract: 量子 k 最小值查找是一个基础且重要的量子算法，在组合问题和机器学习中有许多应用。以往方法往往假设有精确的函数值查询喻示作为算法输入，这使得其不容易与其他量子算法相组合。我们在 van Apeldoorn, Gilyén, Gribling 和 de Wolf 等人工作的基础上，提出了一个新的只使用近似值查询喻示的量子 k 最小值查找算法，该算法具有近似最优的复杂度。作为该算法的实际应用，我们提出了用于识别多个可观测量中的 k 个最小期望值，以及确定具有已知本征基的哈密顿量的 k 个最低基态能量的高效的量子算法。

15:00-15:30, Apr. 17, Thursday Speaker: Zhan Yu

Title: Quantum signal processing in machine learning and algorithm design

Abstract： Quantum Signal Processing (QSP) has emerged as a unifying framework that enables the precise manipulation of quantum amplitudes through the composition of simple unitary operations. This talk explores how QSP serves as a powerful algorithmic primitive in both quantum machine learning and quantum algorithm design. We first delve into the expressive power of QSP-based parameterized quantum circuits (PQCs), which can approximate a broad class of continuous functions—paving the way for PQCs that rival or surpass their classical counterparts in machine learning. We then develop the multi-qubit generalization of QSP, which provides a powerful framework for efficient quantum algorithm design. Throughout the talk, we emphasize the interplay between rigorous algorithmic guarantees and practical circuit implementations, illustrating how QSP bridges theoretical insights in quantum algorithms and quantum machine learning.

9:00-10:00, Apr. 18, Friday Speaker: Penghui Yao

Title: Some Applications of Pauli analysis on Quantum Algorithms and Complexity

Abstract: Fourier analysis is playing a pivotal role in designing quantum algorithms. Recently, Fourier analysis on the space of operators and the space of super-operators, which is termed as Pauli analysis, has received increasing attention. It has found connections to various areas of quantum computing. In this talk, I will introduce some background on Pauli analysis and present some recently discovered applications in quantum learning theory and quantum complexity theory.

10:30-11:00, Apr. 18, Friday Speaker: Yadong Wu

Title: 神经网络学习量子系统

Abstract: 人工智能技术已广泛应用于解决各类物理问题，包括量子信息与量子计算领域。与此同时，高效测量并学习未知量子系统及预测其特性，已成为近期量子信息与量子机器学习研究的热点。在本报告中，我将展示一系列利用神经网络算法表征未知量子系统的研究成果。在这些研究中，我们通过神经网络算法从随机采样的测量数据中提取量子系统的经典表示，并基于该表示准确预测量子系统的物理特性。这一系列工作为多体量子系统和光学量子系统的刻画与表征提供了一个数据驱动的方法框架。

11:00-11:30, Apr. 18, Friday Speaker: Lingling Lao

Title: Decoding algorithms for surface codes

Abstract: The primary obstacle to achieving large-scale reliable quantum computing is noise. Quantum error correction (QEC) addresses this by encoding multiple noisy physical qubits into a logical qubit. One can exponentially suppress the logical error rate by increasing the code distance when the physical error rate falls below a specific threshold. The performance of decoding directly affects the logical error rates, and the decoding speed must exceed the cycle time of a QEC round. This talk will discuss different decoding algorithms for surface codes.

11:30-12:00, Apr. 18, Friday Speaker: Xuanqiang Zhao

Title: Advantages of indefinite causal order in communication

Abstract: We develop a resource theory of communication that incorporates indefinite causal order. We show that, given the same amount of resource, there are instances where causally indefinite operations offer explicit advantages over causally definite ones. However, for Pauli channels, we find that causally definite operations perform equally well as causally indefinite ones, indicating no advantage from indefinite causal order in this case. Our framework allows for a direct comparison of operations with different causal structures on an equal footing and can be extended to other resource theories beyond communication, providing a foundational step towards understanding the advantages of indefinite causal order in various quantum information processing tasks.

List of Participants

姓名	单位
安冬	北京大学
柏舸	香港科技大学（广州）
陈俣翱	香港科技大学（广州）
陈天恩	中国科学院数学与系统科学研究院
陈秋豪	武汉大学
董得宽	复旦大学
方堃	香港中文大学（深圳）
高斌	中国科学院数学与系统科学研究院
高力	武汉大学
高敏博	中国科学院软件研究所
郭乃绪	新加坡国立大学
郭汝驰	四川大学
胡俊鹏	上海交通大学
黄劲松	香港中文大学（深圳）
焦雨领	武汉大学
金石	上海交通大学
赖志坚	北京大学 北京国家数学研究中心
劳玲玲	国防科技大学
李绎楠	武汉大学
李颖洲	复旦大学
李泽通	香港科技大学（广州）
李泽贤	香港理工大学
林鸿鸿	中国科学院数学与系统科学研究院
刘金国	香港科技大学（广州）
刘霞	香港科技大学（广州）

马楚雯	上海交通大学
莫垠	香港科技大学（广州）
聂涵韬	北京大学
欧丰宁	南京大学
彭任锋	中国科学院数学与系统科学研究院
尚云	中科院数学与系统科学研究院
邵长鹏	中国科学院数学与系统科学研究院
王杰	中国科学院数学与系统科学研究院
王天宇	复旦大学上海数学中心
王威	中国科学院数学与系统科学研究院
王鑫	香港科技大学（广州）
吴步娇	深圳国际量子研究院
吴亚东	上海交通大学
席政军	陕西师范大学
杨宇翔	香港大学
杨俨	中科院数学与系统科学研究院
幺宏顺	香港科技大学（广州）
姚鹏晖	南京大学
余展	新加坡国立大学
袁海东	香港中文大学
张宇欣	中国科学院数学与系统科学研究院
赵炫强	香港大学
朱成开	香港科技大学（广州）
朱黄俊	复旦大学

Half-day Tour Arrangement

线路	时间	行程
宜良九乡溶洞全景游	13: 00	柴石滩接团出发
	14:00-17:00	抵达游览九乡溶洞景区
	17:00-18:00	前往宜良学成饭店
	18:00-19:00	晚餐特色烤鸭宴
	19:00-20:00	返回柴石滩

Access Guide

· 地理位置

中心位于云南省昆明市宜良县柴石滩水库库区内国家一级公益林中；三面环山，一面向水，环境优美，风景秀丽、气候宜人；海拔为 1700 米，距离昆明长水国际机场约 90 公里，乘车时间约 1.5 小时。距离石林风景区 25 公里，距离九乡风景区 17 公里。

· 专车服务

中心周日全天接机、接站，周五下午、周六全天安排车辆送机、送站。其他时间需自行解决交通问题，中心可协助联系车辆，但费用需自理。

由于中心外部道路尚未完善，建议参会人员尽量不要选择夜间行车。

· 出租车网约车

昆明长水国际机场或昆明南站，乘坐出租车网约车到柴石滩水库风景区天元数学国际研究交流中心下车。中途经过宜良县城，宜良县城至天元数学国际研究交流中心，有两条线路可供选择：

（一）宜良县城上汕昆高速，往石林方向，石林风景区下高速，走九石阿公路到达柴石滩水库风景区天元数学国际研究交流中心。这条线路，路面宽，急弯道少，路况相对较好。

昆明长水国际机场至天元数学国际研究交流中心全程 99 公里，一般需要 1 小时 30 分钟；

昆明南站至天元数学国际研究交流中心全程 92 公里，一般需要 1 小时 20 分钟。

（二）走古柴段线路到达柴石滩水库风景区天元数学国际研究交流中心。这条线路，需要经过村镇，路面窄，急弯道多，路况相对较差。

昆明长水国际机场至天元数学国际研究交流中心全程 74 公里，需要 1 小时 25 分钟；

昆明南站至天元数学国际研究交流中心全程 78 公里，需要 1 小时 35 分钟。

· 公共交通

1、 昆明长水国际机场乘坐地铁 6 号线到昆明东部客运站下车，乘坐昆明至宜良大巴车到宜良客运站下车，或昆明南站乘坐昆明高铁南客运中心至宜良大巴车到宜良客运站下车，乘坐 20 路公交车到北古城镇下车，乘坐 5 路公交车到柴石滩水库下车。下车终点站距离天元数学国际研究交流中心约 4 公里，联系工作人员接送。

2、 公共交通工具运营时间地铁 6 号线首班时间 6：20，末班时间 23：00，运营间隔为 25 分钟。

昆明至宜良大巴车首班时间 7：00，末班时间 21：00，运营间隔为 1 小时。

宜良 20 路公交车首班时间 7：00，末班时间 19：00，运营间隔为 30 分钟。

宜良 5 路公交车首班时间 8：00，末班时间 18：00，运营间隔为 2 小时。

注：宜良 5 路、20 路，逢日期尾号 3、6、9 才有班车

· 自驾

自驾可使用导航搜索“天元数学国际研究交流中心”定位，依据导航指引可到达天元数学国际研究交流中心。

Tianyuan Mathematics Research Center

天元数学国际交流中心由中国科学院、国家自然科学基金委员会、中国数学会、中国科学院数学与系统科学研究院，以及昆明市有关部门共同支持建设的数学与交叉科学交流机构。旨在搭建数学及其跨学科应用领域的学术交流平台，提升我国数学整体研究水平，成为国际一流的数学交流与合作研究中心。

该中心位于云南省昆明市宜良市柴石滩水库库区的国家级公益林内，三面环山，一面环水。该中心总用地面积约 2.7 万平方米，有研究楼、专家楼和后勤楼三栋两层主楼，可容纳近 200 人进行学术活动，并配有图书馆和阅览室、餐厅以及一定数量的办公和住宿用房。

该中心将聚焦数学科学的重大前沿方向和重大问题，组织开展形式多样的国内外优秀专家学术交流与合作研究活动，推动实质性合作研究形成优势方向，促进数学学科发展。同时，该中心将重点培养青年人才，普及数学科学，增强公众对数学科学的认识，提高我国数学的整体研究水平，努力建设国际一流的数学交流与合作研究中心。

该中心将支持数学科学的主要方向。在基础数学领域，应该布局对未来数学有重大领导作用的方向，包括数论和代数、几何和拓扑学、现代分析和数学物理、概率论和随机分析。在应用数学领域，应布局国家战略急需的应用数学关键通用方法领域，包括数据科学与人工智能数学理论、科学与工程计算方法、复杂系统优化与控制理论、计算机数学与密码学等。该中心还支持多样化的学术研究，不仅在数学学科，而且在与数学交叉的领域，如物理、医学、生物学和信息等。该中心将邀请相关领域的顶尖专家，特别是活跃在其领域前沿的杰出年轻研究人员，进行合作和交流，从而通过多学科的交叉融合，产生新的思想，推动重大问题的解决。

中心将借鉴国际顶尖学术交流机构的成功经验，建立合理的机构运作和活动组织机制。该中心不会设立常设研究职位，工作人员的流动性将与学术活动的多样性相匹配。中心将组织学术活动，包括研讨会、著名学者系列讲座和青年研讨会、暑期研究生课程等。中心学术委员会将负责规划和验证中心的学术主题和活动。所有活动都向国内数学界开放。在中心成立初期，学术活动主要以每周一次的研讨会为基础。