2018 Mini-Workshop on Design Theory and Quantum Information

上海大学
Shanghai University

Shanghai University

Shanghai, China

June 13-15, 2018

Organized by

International Research Center for Tensor and Matrix Theory (IRCTMT), SHU
Department of Mathematics, SHU

Supported by

International Research Center for Tensor and Matrix Theory (IRCTMT), SHU

2018 Mini-Workshop on Design Theory and Quantum Information

Purpose

Recent years have witnessed a rapid and strong interaction between algebraic combinatorics, in particular design theory, and quantum information theory. It is timely to have a mini-workshop dedicated to the design theory and quantum information theory, where world experts in this field introduce their recent research outcomes. It is expected that this workshop will facilitate further interactions and boost collaborations among participants.

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Organizing Committee

Organizing Committee

Mikio Nakahara, Shanghai University, China

Eiichi Bannai, Kyushu University (emeritus), Japan & TGMRC, China

Yoshifumi Nakata, University of Tokyo, Japan

Yan Zhu, Shanghai University, China

Local Organizing Committee

Mikio Nakahara (**Chair**)

Qing-Wen Wang

Xin-Jian Xu

Yan Zhu

Fuping Tan

Xiaomei Jia

Lingji Lou

Yang Ding

Invited Speakers

Eiichi Bannai	Kyushu University (emeritus), Japan & TGMRC, China
Min Jiang	USTC, China
Yoshifumi Nakata	University of Tokyo, Japan
Takayuki Okuda	Hiroshima University, Japan
Sho Suda	Aichi University of Education, Japan
Yasunari Suzuki	NTT, Japan
Wei-Hsuan Yu	Brown University, USA
Huangjun Zhu	Fudan Univesity, China
Yan Zhu	Shanghai University, China

Information for Participants

Workshop agenda

06.13	*Registration (9:00-19:00)* *Venue: Lobby of Lehu New Hotel*
06.14-06.15	*Conference(Xuesi Hall & Haina Hall)*

Accommodation

New Lehu Hotel, Shanghai University,716 Jinqiu Road
上海市宝山区锦秋路 716 号上海大学北大门乐乎新楼 2 号楼

Transportation

1. Pudong Airport

By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 250 RMB.)

By Metro: Metro Line 2 to Jing'an Temple exchange to Metro Line 7 to Shanghai University. (Total price is 8 RMB.)

2. Hongqiao Airport & **Shanghai Hongqiao Railway Station:**

By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 70 RMB.)

By Metro: Metro Line Line 2 to Jing'an Temple exchange to Metro Line 7 to Shanghai University(Baoshan Campus). (Total price is 6 RMB.)

3. Shanghai Railway Station

By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 50 RMB.)

By Metro: Metro Line 3 to Zhenping Road exchange to Metro Line 7 to Shanghai University(Baoshan Campus). (Total price is 4 RMB.)

Contact Us

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Website: http://math.shu.edu.cn/DTQI2018/

Program

June 13, 2018 (Wednesday)

Time	Venue: Lobby of Lehu Hotel (乐乎新楼 1 号楼大厅)
Whole day	**Registration**
17:30-19:30	**Dinner**

June 14, 2018(Thursday)

Time	Venue: **Xuesi Hall(学思厅)**	
	Speaker\Title	Chair
09:00-09:30	**Opening Ceremony** **1. Welcome Speech** **2. Photo-taking**	
09:30-10:30	**Yoshifumi Nakata** *Symmetric random unitary -its application to the black hole information paradox-*	**Yasunari Suzuki**
10:30-11:00	**Coffee/Tea**	
11:00-12:00	**Huangjun Zhu** *Generalized Entanglement Entropies of Quantum Designs*	**Yasunari Suzuki**
12:00-13:30	**Lunch**	
13:30-14:30	**Takayuki Okuda** *Double integrations and designs*	**Sho Suda**
14:30-15:00	**Coffee/Tea**	
15:00-16:00	**Yan Zhu** *Tight complex spherical designs*	**Wei-Hsuan Yu**
16:00-17:00	**Eiichi Bannai** *On unitary designs and codes*	
18:00	**Dinner**	

June 15, 2018(Friday)

Time	Venue: **Haina Hall(海纳厅)**	
	Speaker\Title	Chair
09:00-10:00	**Min Jiang** *Experimental Benchmarking of Quantum Control in Zero-Field Nuclear Magnetic Resonance*	**Huangjun Zhu**
10:00-10:30	**Coffee/Tea**	
10:30-11:30	**Yasunari Suzuki** *On the random test for quantum computer*	**Huangjun Zhu**
11:30-13:30	**Lunch**	
13:30-14:30	**Sho Suda** *Complex spherical designs and codes*	**Yan Zhu**
14:30-15:00	**Coffee/Tea**	
15:00-16:00	**Wei-Hsuan Yu** *Recent progress of maximum equiangular lines*	**Yan Zhu**
16:00-17:00	**Free Discussion**	
18:00	**Dinner**	

Note：Xuesi Hall （The 1st floor of New Lehu Hotel）;

Haina Hall（The 2nd floor of New Lehu Hotel）

Abstract

Name: Yoshifumi Nakata, nakata@qi.t.u-tokyo.ac.jp

Affiliation: Photon Science Center, Graduate School of Engineering, The University of Tokyo, Japan.

Title: Symmetric random unitary -its application to the black hole information paradox-

Abstract: A Haar random unitary, a random unitary uniformly distributed over the unitary group, has a wide range of applications in quantum information science, from quantum communication and computation to fundamental physics such as quantum black hole science and quantum chaos. In this talk, we first overview in brief the use of random unitaries and unitary designs in quantum information science. We then focus on the black hole information paradox, an elegant solution of which was proposed by Hayden and Preskill by identifying the internal dynamics of black holes with a Haar random unitary. Although their result had a big impact on the field, their solution may not be directly applicable to real physics since no physical properties of black holes were taken into account in their analysis. We here revisit the information paradox when a black hole has a symmetry, which obviously prevents the internal dynamics from being fully random. By exploiting the idea of a *symmetric* random unitary and developing the *one-shot partial decoupling* technique, we explicitly show what information is easy/hard to leak out from the black hole with a symmetry. We also point out the possibility to experimentally test the information paradox in non-integrable quantum many-body systems. Finally, we would like to discuss quantum circuit implementations of symmetric random unitaries, which we believe is of independent interest.

Co-author(s): Eyuri Wakakuwa, and Masato Koashi

Name: Huangjun Zhu, zhuhuangjun@fudan.edu.cn

Affiliation: Department of Physics, Fudan University, Shanghai, China

Title: Generalized Entanglement Entropies of Quantum Designs

Abstract: The entanglement properties of random quantum states or dynamics are important to the study of a broad spectrum of disciplines of physics, ranging from quantum information to high energy and many-body physics. This work investigates the interplay between the degrees of entanglement and randomness in pure states and unitary channels. We reveal strong connections between designs (distributions of states or unitaries that match certain moments of the uniform Haar measure) and generalized entropies (entropic functions that depend on certain powers of the density operator), by showing that Rényi entanglement entropies averaged over designs of the same order are almost maximal. This strengthens the celebrated Page's theorem. Moreover, we find that designs of an order that is logarithmic in the dimension maximize all Rényi entanglement entropies and so are completely random in terms of the entanglement spectrum. Our results relate the behaviors of Rényi entanglement entropies to the complexity of scrambling and quantum chaos in terms of the degree of randomness, and suggest a generalization of the fast scrambling conjecture.

Co-author(s): Zi-Wen Liu, Seth Lloyd, and Elton Yechao Zhu

Name: Takayuki Okuda, okudatak@hiroshima-u.ac.jp

Affiliation: Hiroshima University

Title: Double integrations and designs.

Abstract: Let X be a compact topological space with a probability Radon measure. For a given continuous functional spaces, we can define designs for the functional space naturally.

Let us consider the following situation, (i) X can be decomposed as a fiber bundle with a base space Y and a fiber F. Y and F are equipped with a probability Radon measures. (ii) The double integration of each continuous function through the fiber bundle is the integral of the function over X. In fact, double integrations can be formulated for general equivalent maps between compact homogeneous spaces.

In this talk, we study that if we have a design on the base space Y and a design of the fiber F, then we can construct a designs on X. In particular, we discuss such the idea for unitary designs.

Name: Yan Zhu, zhu_yan@shu.edu.cn

Affiliation: Shanghai University, China

Title: Tight complex spherical designs

Abstract: Let $\mathcal{T} \subset \mathbb{N} \times \mathbb{N}$ and $\Omega(n)$ be the unit sphere in $\mathbb{C}^n$. For any $z = (z_1, \cdots, z_n) \in \Omega(n)$, denote $\mathrm{Hom}(k, \ell)$ as the set of polynomials in z which are homogeneous of degree k in $\{z_1, \ldots, z_n\}$ and homogeneous of degree ℓ in $\{\bar{z}_1, \ldots, \bar{z}_n\}$. A finite subset X on the unit complex sphere $\Omega(n)$ is called a complex spherical $\mathcal{T}$-design if

$$\frac{1}{|\Omega(n)|} \int_{\Omega(n)} f(z) \mathrm{d}z = \frac{1}{|X|} \sum_{z \in X} f(z)$$

for every $f(z) \in \mathrm{Hom}(k, \ell)$ with $(k, \ell) \in \mathcal{T}$. We focus on complex spherical $\mathcal{T}$-designs with $\mathcal{T} = \{(k, \ell) \mid 0 \leq k + \ell \leq t\}$. A design is called *tight* if its size attains some lower bound. In this talk, we will discuss the existence of such tight designs.

Co-author(s): Eiichi Bannai, Etsuko Bannai, Takayuki Okuda and Da Zhao.

Name: Eiichi Bannai, bannai@math.kyushu-u.ac.jp

Affiliation: Kyushu University (emeritus), Japan, and TGMRC, Yichang, P. R. China

Title: On unitary designs and codes

Abstract: The purpose of this talk is to have some very informal discussions on (exact) unitary t-designs, from the viewpoint of mathematics (algebraic combinatorics). We start with the review on the paper by Aidan Roy and Andrew Scott: On unitary designs and codes (Designs, Codes and Cryptography, 2009). We will discuss on tight unitary $2s$-designs, and in particular on more special class of unitary $2s$-designs which are s-distance sets, including the discussion on what is the best formulation of this problem. Here, some new ideas and methods due to Ziqing Xiang (University of Georgia) are very crucial, and we will explain about these.

Name: Min Jiang, dxjm@mail.ustc.edu.cn

Affiliation: CAS Key Laboratory of Microscale Magnetic Resonance and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Title: Experimental Benchmarking of Quantum Control in Zero-Field Nuclear Magnetic Resonance

Abstract: Demonstration of coherent control and characterization of the control fidelity is important for the development of quantum architectures such as nuclear magnetic resonance (NMR). Here, we introduce an experimental approach to realize universal quantum control, and benchmarking thereof, in zero-field NMR, an analog of conventional high-field NMR that features less-constrained spin dynamics. We design a composite-pulse technique for both arbitrary one-spin rotations and a two-spin controlled-not (CNOT) gate in a heteronuclear two-spin system at zero field, which experimentally demonstrates universal quantum control in such a system. Moreover, using quantum-information-inspired randomized benchmarking and partial quantum process tomography, we evaluate the quality of the control, achieving single-spin control for ^{13}C with an average fidelity of 0.9960(2) and two-spin control via a CNOT gate with a fidelity of 0.9877(2). Our method can also be extended to more general multi-spin heteronuclear systems at zero field. The realization of universal quantum control in zero-field NMR is important for quantum state/coherence preparation, pulse-sequence design, and is an essential step towards applications to materials science, chemical analysis, and fundamental physics..

Co-author(s): Teng Wu, John W. Blanchard, Guanru Feng, Xinhua Peng, Dmitry Budker

Name: Yasunari Suzuki, suzuki.yasunari@lab.ntt.co.jp

Affiliation: NTT Secure Platform Laboratory

Title: On the random test for quantum computer

Abstract: Quantum computation is a framework to utilize properties of quantum mechanics for computation. Since quantum computer is believed to be capable of faster processing than classical ones in a variety of tasks, massive efforts have been paid for developing it. Since the computational power of quantum computer is limited by achievable quality and quantity of quantum bits (qubits), it is required to characterize noise in qubits and improve them. Thanks to recent experimental developments, various quantum devices have been scaled up with keeping long lifetime and high controllability. However, when we start to build quantum devices with more than 50 qubits

and small noise, we encounter several new problems. In particular, one of the most difficult problems is to characterize properties of noise in qubits with sufficient precision using practical experimental resource. Since the degrees of freedom in noise increase exponentially to the number of qubits, characterization methods based on a brute-force approach are not practical. Furthermore, since state preparation and measurement process suffer from noise, it is also hard to precisely distinguish noise in quantum controls from state preparation and measurement noise (SPAM noise). Therefore, a new method which enables efficient and precise characterization of noise is demanded.

Characterization methods based on random testing are expected to solve these problems. By performing a sequence of random operations picked from a certain set, some properties of noise can be precisely characterized with a practical number of experiments. So far, various methods based on random testing for many purposes are suggested. For example, randomized benchmarking [E. Knill *et al.*, Phys. Rev. A. **77**, 012307 (2007)] is one of the most popular approaches. This method enables us to estimate an averaged error probability of quantum operations independently of the SPAM noise by performing random Clifford operations. However, it is hard to use this method for quantum devices with more than a few tens of qubits. Another popular one is a benchmarking method using random universal quantum operations [C. Neill *et al.*, Science **13**, 360, 6385 pp. 195-199 (2018)]. This method enables estimation of an amount of noise in quantum devices and is expected to be applicable to more than 40 qubits [S. Boixo *et al.*, arXiv:1608.00263 (2016)]. On the other hand, this method requires massive classical computation for evaluation. Recently, we have suggested a new method based on random testing using random fermionic Gaussian operations. This method is expected to be scalable and does not require massive classical computation. In this talk, we review a basic framework of quantum computer, and explain about existing and proposed methods for noise characterization.

Name: Sho Suda, suda@auecc.aichi-edu.ac.jp

Affiliation: Department of Mathematics Education, Aichi University of Education, Japan

Title: Complex spherical designs and codes

Abstract: We review the work on complex spherical designs and codes

with Aidan Roy. We focus on a relationship with commutative association schemes, and demonstrate that some complex MUBs and SIC-POVMs provide good finite point sets in complex unit sphere and commutative association schemes based on the theory of complex spherical designs and codes.

Co-author(s): Aidan Roy

Name: Wei-Hsuan Yu, u690604@gmail.com

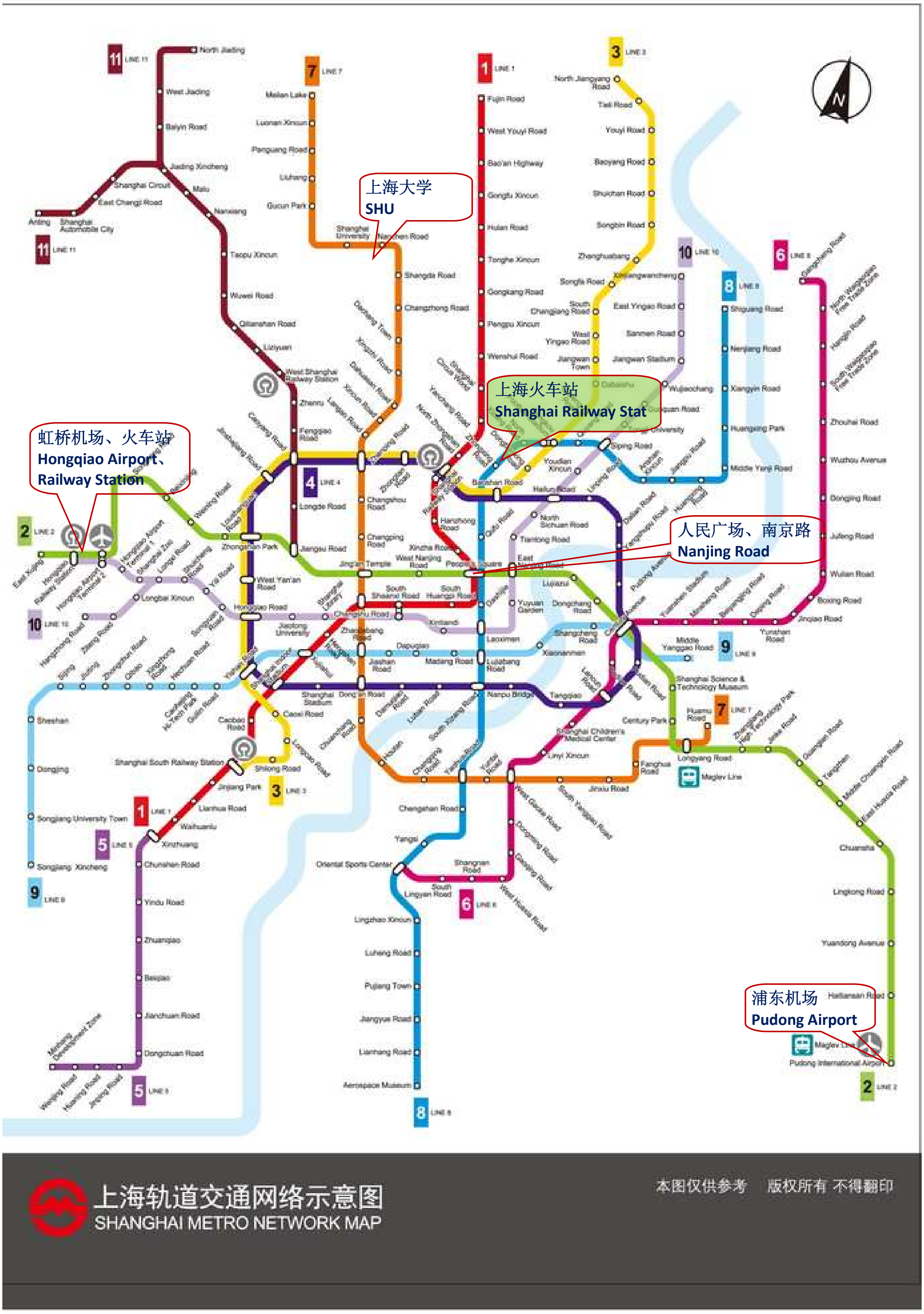
Affiliation: ICERM, Brown University

Title: Recent progress of maximum equiangular lines

Abstract: A set of lines is called equiangular if the angle between each pair of lines is the same. We address the question of determining the maximum size of equiangular lines. We will talk about recent progress of maximum equiangular lines.

Shanghai University Map (Baoshan Campus)

Metro Map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SHANGHAI METRO NETWORK MAP
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