PLUS⁺ Training and Development Program

APR

Four Assorted Quantum Pieces

Dr. Karol Życzkowski

Talk 1. On distances in the space of quantum states

Various distances between two quantum states are discussed. Some properties and meaning of the trace, Hilbert-Schmidt and Bures distances and Bures angle related to fidelity will be reviewed, and some useful bounds will be given. More recent results on the transmission distance (square root of the Jensen-Shannon divergence) and the transport distance, related to the Earth-Mover distance of Monge-Kantorovich will also be presented [1]. It is fair to expect that these different distances will find their applications in quantum information and machine learning**.**

[1] S. Friedland, M. Eckstein, S. Cole and K. Życzkowski, Quantum Monge-Kantorovich problem and transport distance between density matrices, preprint arXiv:2102.07787

Talk 2. Quantum chaos for open systems: Universal spectra of random Lindblad operators

The spectrum of generic superoperators, corresponding to random stochastic operations, displays a universal behaviour: it contains the leading eigenvalue λ1= 1, while all other eigenvalues are restricted to the disk of radius R<1. In the case of generic dynamics in continuous time, we introduce an ensemble of random Lindblad operators, demonstrate its spectral features including the lemon-like shape of the spectrum in the complex plane, and explain them with a non-hermitian random matrix model [2]. We show how such spectra are modified due to superdecoherence, which leads to Kolmogorov operators, which generate Markovian evolution in the simplex of classical probability vectors.

[2] J. Czartowski, D. Goyeneche, M. Grassl and K. Życzkowski, Iso-entangled mutually unbiased bases, symmetric quantum measurements and

Calendar

- **Tuesday 20th April 10:00 – 12:00 via Zoom**
- **Tuesday 27th April 10:00 – 12:00 via Zoom**

ICFO

PLUS+ Training and Development Program

MAY

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Talk 3. Iso-entangled Mutually Unbiased Bases and Mixed-state t-designs

A Euclidean design is a finite set of points in Rn with certain approximation properties. This concept can be generalized to give the notion of pure-state designs: vectors selected in such a way that the average values of the first t moments averaged over the design coincide with the moment obtained by integrating over the set of all states. We introduce a related notion of a mixed-state t-design, which consist of a finite number of density matrices of order N with analogous properties. Mixed-state designs can be obtained by partial trace of pure states of size N2 forming a pure state design. We construct a set of five iso-entangled Mutually Unbiased Bases (MUBs) in H4, consisting of 20 pure states with the same degree of entanglement. Performing a partial trace on any of both subsystems leads to 20 single-qubit mixed states which form a regular dodecahedron inside the Bloch ball and a mixed 3-design [3].

[3] S. Denisov, T. Laptyeva, W. Tarnowski, D. Chruściński and K. Życzkowski, Universal spectra of random Lindblad operators, Phys. Rev. Lett. 123, 140403 (2019).

Talk 4. Quantum designs and Absolutely Maximally Entangled (AME) states.

An AME state of a system consisting of 2k parties is distinguished by the fact that for any splitting of the system into two parts with k subsystem each, both parties are maximally entangled. Such states, useful to construct quantum error-correction codes and teleportation schemes, are known for several systems including four systems with N=3,4,5,7,8... levels each and a six-qubit system. We show that the AME(4,6) state of four subsystems with six levels each exists and present an analytical solution, equivalent to a 2-unitary matrix of order 36 and a perfect tensor with 4 indices running from one to six [4]. Furthermore, it yields a quantum error correcting ((3,6,2))6 code and can be considered as a quantum solution of the famous 36-officers problem of Euler with entangled officers. We tend to believe this result will trigger further research in the field of quantum designs and quantum combinatorics.

[4] S. A. Rather. A. Burchardt, W. Bruzda, G. Rajchel-Mieldzioć, A. Lakshminarayan, and K. Życzkowski, Thirty-six entangled officers of Euler and a quhex quantum error correcting code, preprint, April 2021

Calendar

- **Tuesday 4th May 10:00 – 12:00 via Zoom**
- **Tuesday 11th May 10:00 – 12:00 via Zoom**