Entanglement Transformation between Sets of Bipartite Pure States by Local Operations Alone

H.F. Chau
The University of Hong Kong

Abstract
Here I report a team work resulting from the fruitful collaboration started by this workshop. In collaboration with C.-H. F. Fung, C.-K. Li, E. Poon and N.-S. Sze, we considered the following problem aft er last year's workshop. Suppose Alice and Bob are given an unknown initial state chosen from a set of pure quantum states. They wanted to convert it into a corresponindg final pure state by local operations only. We report a necessary and sufficient condition for the existence of such a transformation as well as an efficient algorithm to quickly rule out most of the possibilities for such a transformation. This work has been published recently as J.Math.Phys. 53, 122201 (2012).

Adaptive Trajectory Tracking of Quantum Systems

Shuang Cong
University of Science and Technology of China

Abstract
A control strategy for tracking the trajectory of a time-variant objective function in closed quantum systems is proposed in this paper. The Lyapunov stability theorem is used to design the control law. Meanwhile, the issue of singularity is discussed and the problem of large value of control field occurred during the process of tracking are solved by using an adaptive regulation algorithm of objective function. Simulation results demonstrate the effectiveness and feasibility of the method proposed. We also explore the relationship of effect between control parameters and the error of the control system.

TBA

Hong-Yi Dai
National University of Defense Technology

Abstract

Disguising Quantum Channels by Mixing and Channel Distance Trade-off

Chi-Hang Fred Fung
University of Hong Kong

Abstract
We consider the reverse problem to the distinguishability of two quantum channels, which we call the disguising problem. Given two quantum channels, the goal here is to make the two channels identical by mixing with some other channels with minimal mixing probabilities. This quantifies how much one channel can disguise as the other. In addition, the possibility to trade off between the two mixing probabilities allows one channel to be more preserved (less mixed) at the expense of the other. We derive lower- and upper-bounds of the trade-off curve and apply them to a few example channels. Optimal trade-off is obtained in one example. Relation with the diamond norm is also discussed.

Co-authors H.F. Chau (The University of Hong Kong)

Geometric Quantum Gates Based on Dynamical Invariants

Utkan Güngördü
Kinki University

Abstract
We employ a Lie-algebraic approach to obtain exact dynamical invariants, also known as Lewis-Riesenfeld invariants, of practical single and two-qubit systems. We use these invariants to obtain non-adiabatic geometric quantum gates.

Co-authors Yidun Wan (University of Tokyo), Mohammad Ali Fasihi (Kinki University), Mikio Nakahara (Kinki University)

Quantum Measurement Maps and Maps Preserving Convex Combinations of Quantum States

Kan He
Taiyuan University of Technology

Abstract
The bijective map preserving convex combinations of quantum states must be an invertible measurement map or the composition of the transpose map with an invertible measurement map. Furthermore, the case of bipartle systems also be discussed.

Co-authors Jinchuan Hou (Taiyuan University of Technology), Chi-Kwong Li (College of William and Mary)

Simplicial Faces and Lengths for Separable States

Seung-Hyeok Kye
Seoul National University

Abstract

In order to understand the convex structures of the convex set consisting of all separable bipartite states, we consider the notions of simplicial faces of the convex set and lengths of separable states. We say that a face is *simplicial* if it is affinely isomorphic to a simplex. It is clear that an interior point of a simplicial face has a unique decomposition into pure product states. Conversely, if a separable state has a unique decomposition then the smallest face determined by the state is simplicial. The length of a separable state ϱ is defined by the smallest number k for which ϱ is decomposed into k pure product vectors. If ϱ is an interior point of a simplicial face Δ_{k-1} with k vertices, then it is clear that the length of ϱ is equality to k. More generally, it will be shown that the length is invariant on the interior of a given face. If $k \le m+n-2$ then it is known that generic choices of k product vectors give rise to simplicial faces isomorphic to Δ_{k-1}. In this talk, we will concentrate on simplicial faces Δ_{k-1} with $k \ge m+n-1$.

In the two qutrit cases, we show that generic 5-dimensional subspaces of $\mathbf{C}^3 \otimes \mathbf{C}^3$ give rise to simplicial faces isomorphic to Δ_5 with six vertices. As for the interior points, some of them are of symmetric type, that is, the ranks of itself and its partial transpose coincide. Some of them are of asymmetric type. We have various applications. For examples, we show that every rank four PPT entangled states is the difference of two rank five separable states; the structural physical approximation conjecture fails even for decomposable cases. We also show that the Choi type positive linear maps are exposed, and their dual faces have length 10, strictly greater than the number $3 \times 3 = 9$, to disprove a conjecture. The maximality of these faces shows that adding a separable state may decrease the length strictly. We also found some subfaces of them are simplicial and isomorphic to Δ_9, with which we see that there exist simplicial faces isomorphic to Δ_k for every $k \le 9$. In the qubit-qu$d$it cases, we also show that generic choices of $d+1$ product vectors give rise to simplicial faces isomorphic to Δ_d. We will also discuss to what extents our arguments may work for general cases.

This talk is based on two preprints arXiv:1211.5675 and arXiv:1210.1088 with Kil-Chan Ha.

Co-authors Kil-Chan Ha (Sejong University)

Basic Results in Quantum Computing and Elementary Linear Algebra

Chi-Kwong Li
College of William and Mary

Abstract
We use elementary linear algebra techniques to explain some basic results in quantum computing such as the universality of elementary quantum gates and some simple quantum algorithms.

Absolutely Maximally Entangled (AME) States

Hoi-Kwong Lo
University of Toronto

Abstract
We study the existence of absolutely maximally entangled (AME) states in quantum mechanics and its applications to quantum information. AME states are characterized by being maximally entangled for all bipartitions of the system and exhibit genuine multipartite entanglement. With such states, we present a novel parallel teleportation protocol which teleports multiple quantum states between groups of senders and receivers. The notable features of this protocol are that (i) the partition into senders and receivers can be chosen after the state has been distributed, and (ii) one group has to perform joint quantum operations while the parties of the other group only have to act locally on their system. We also prove the equivalence beJourntween pure state quantum secret sharing schemes and AME states with an even number of parties. This equivalence implies the existence of AME states for an arbitrary number of parties based on known results about the existence of quantum secret sharing schemes.

Journal Reference: W. Helwig, W. Cui, J. I. Latorre, A. Riera, and H.-K. Lo, Phys. Rev. A 86 052335 (2012).

Concatenated Composite Pulses

Mikio Nakahara
Kinki Univerisity

Abstract
Pulse sequences called composite pulses have been developed in NMR to suppress one of two dominant errors; a pulse length error and an off-resonance error. These composite pulses work as high-precision gates in quantum information processing. We develop a general prescription to design a single-qubit ConCatenated Composite Pulse (CCCP) that is robust against both types of errors simultaneously. We introduce a new condition called the "residual error preserving" condition, which is satisfied by some composite pulses and is a

sufficient condition to implement a CCCP. Then we introduce a general method to design CCCPs with reduced execution time and less number of pulses.

This talk is based on J. Phys. Soc. Jpn. **82** (2013) 014004 (arXiv:1209.4247).

Co-authors Masamitsu Bando (Kinki Univerisity), Tsubasa Ichikawa (Kinki Univerisity), Yasushi Kondo (Kinki Univerisity)

Quantum Error Correction for Phase-flip Errors

Yiu-Tung Poon
Iowa State University

Abstract

We study a quantum error correction code for a quantum channel on n qubits with error operators in the set $\{\mu U \otimes \cdots \otimes U : U = e^{i\gamma H}, \gamma \in \mathbb{R}, \ \mu \in (0,1]\}$ for a fixed trace zero Hermitian matrix H. It is shown that for such a channel there exists quantum error correction codes (realized as a subspace of $\mathbb{C}^{2^n}$) of dimension k if and only if $k \leq \binom{n}{[n/2]}$ where $[n/2]$ is the integral part of $n/2$. Since

$$\lim_{n\to\infty} \frac{1}{n} \log_2 \binom{n}{[n/2]} = 1,$$

it follows that the information correction rate approaches 1.

Constructing Optimal Entanglement Witnesses by Permutations

Xiaofei Qi
Shanxi University

Abstract

A linear map $\Phi_D : M_n \to M_n$ is called a D-type map if Φ_D has the form $(a_{ij}) \longmapsto \mathrm{diag}(f_1, f_2, ..., f_n) - (a_{ij})$ with $(f_1, f_2, ..., f_n) = (a_{11}, a_{22}, ..., a_{nn})D$ for an $n \times n$ nonnegative matrix $D = (d_{ij})$ (i.e., $d_{ij} \geq 0$ for all i, j). For any permutation π of $\{1, 2, \ldots, n\}$ and $t \geq 0$, let $\Phi_{t,\pi} : M_n \to M_n$ be the D-type map of the form with $D = (n-t)I_n + tP_\pi$. In this talk, we give necessary and sufficient conditions for $\Phi_{t,\pi}$ becoming positive, indecomposable and optimal, respectively.

Co-authors Jinchuan Hou (Taiyuan University of Technology)

Fundamental Quantum Limits to Waveform Sensing

Mankei Tsang
National University of Singapore

Abstract
Recent technological advances suggest that quantum effects will soon become relevant in sensing and metrological applications, such as optomechanical force sensing, gravitational-wave detection, and atomic magnetometry. In this talk I will discuss how the laws of quantum mechanics impose fundamental limits to the detection and estimation of time-varying signals, and how such limits can be approached using estimation and control techniques.

Weak Measurement and its Applications

Shengjun Wu
University of Science and Technology of China

Abstract
The idea of weak measurement was introduced by Aharonov, Albert and Vaidman in 1988. It not only provides a theoretical framework for addressing counterintuitive quantum phenomena and fundamental questions, but also gives a practical tool for amplifying very tiny signals that would not be observed in the conventional measurement schemes. In this talk, I shall review the basic idea of weak measurement, and show explicitly how it can be used for signal amplification. I shall present an extension of weak measurement to general preselection and postselection with corrections to high order terms, and give a general formalism for weak measurement of a pair of complementary observables. I shall also discuss the limitation on amplification of the signal-to-noise ratio and how this limitation can be overcome by simultaneous weak measurements of a pair of complementary observables. I shall also discuss state tomography via weak measurements.

Correlation Polytope and Bell Inequalities

Yuchun Wu
University of Science and Technology of China

Abstract
The structure feature of Clauser-Horne-Shimony-Holt (CHSH) type Bell inequalities which reveals the relationship of CHSH-type Bell inequalities in different dimensions was foound. Based on the structure feature one can in principle derive all kinds of CHSH type Bell

inequalities step by step from lower dimension to higher dimensions. As application, we proposed a method to construct the experimentally friendly CHSH-type Bell inequalities for multipartite cases. The eight-party inequality can be used to verify the violation of local realism for the eight-party GHZ state generated by Huang [Nat. Commun. **2**:546 (2011)].

Implementation of Quantum Walks

Peng Xue
Southeast University

Abstract

First I will talk about the impact of decoherence and disorder on the dynamics of discrete quantum walks and simulate different environment influences on quantum walks resulting in a ballistic spread, Anderson localization and a diffusive random walk. Then I will also talk about how single- and multi-particle quantum walks can be implemented with different physical systems such as ion trap, linear optics and cavity quantum electrodynamics. The implementation of a quantum walk with single- and multi-particle opens up the interesting possibility to introduce entanglement and more advanced walks. With different coin tosses and initial states the quantum walks show different probability distributions which deviate strongly from the classical random walk with quadratic enhanced spreadings and localization effects. By introducing controllable decoherence, the transition from quantum walks to the classical version is observed.

The Generalized Partial Transposition Separability Criterion for Infinite-dimensions Quantum Systems

Siqing Yan
Taiyuan University of Technology

Abstract

Let $H_A, \ldots, H_N$ $(N \geq 2)$ be complex Hilbert spaces of infinite-dimensional. In this paper, the generalized partial transposition criterion of separability for state in infinite-dimensional bipartite and multipartite quantum systems are established. That is, let ρ be a state acting on infinite-dimensional complex Hilbert space $H_A \otimes \cdots H_N$, if ρ is separable, then $\|\rho^{T_y}\|_{\mathrm{Tr}} \leq 1$, where T_y represent the generalized row or column transposition on chosen subsystems (finite-dimensional case see [1]); in particular, if ρ is a pure state, then equal-sign hold. Furthermore, for infinite-dimensional case, we illustrate well-known bipartite PPT criterion [2] and bipartite realignment criterion[3] are included in bipartite generalized

partial transposition criterion; multipartite PPT criterion and multipartite realignment criterion are included in multipartite generalized partial transposition criterion. Some example are also presented to demonstrate how to apply multipartite realignment criterion to detect entanglement of tripartite states.

References

[1] K.Chen, L.A.Wu, Phys.Lett.A 306(2002)14-22.
[2] E.Strømer, J.Funct.Anal.254(2008)2304.
[3] Y.Guo and J.C.Hou, arXiv: quant-ph/1009.0116v1.

Co-authors Jinchuan Hou (Taiyuan University of Technology)

Optimal Control of Quantum Systems

Haidong Yuan
The Hong Kong Polytechnic University

Abstract

Quantum system is rarely isolated but interacts with its environment, this in practice results in signal loss and limits the range of applications. It is therefore of utmost importance to control quantum systems in a time optimal manner before decoherence corrupts the system of interest. In this talk we will focus on the time optimal control of spin systems in quantum computing and spectroscopy where radio frequency pulses are used in coherent spectroscopy to implement transfers of states. Pulse sequences that accomplish a desired transfer should be as short as possible in order to minimize the effects of relaxation and to optimize the sensitivity of measurements. We will give an analytical characterization of some time optimal pulse sequences.

Geometric Measure of Entanglement Using Tensor Spectra

Guofeng Zhang
The Hong Kong Polytechnic University

Abstract

The geometric measure of entanglement for a symmetric pure state with nonnegative amplitudes has attracted much attention. On the other hand, the spectral theory of nonnegative tensors (hypermatrices) has been developed rapidly. In this talk, we show how the spectral theory of nonnegative tensors can be applied to the study of the geometric measure of entanglement for a pure state with nonnegative amplitudes. We show that for the geometric measure of entanglement for pure states with nonnegative amplitudes, the nonsymmetric ones can be converted to the symmetric ones. Some examples are given.

On Robust Quantum Information Processing

Ming Zhang
National University of Defense Technology

Abstract

The purpose of this research is to investigate robust quantum information processing by exploring quantum teleportation. It is well known that with the help of entangled EPR pair (the maximal entangle state), Alice can send unknown quantum information to Bob with classical communication. When it comes to practical quantum teleportation, robustness issues, however, should be taken into consideration. Some observations are given as follow. When only non-maximal entangled state is available, Alice can finish the mission of sending unknown quantum information with some partial success probability, which depends on the coefficient of entangled state. Furthermore, from the viewpoint of physical operation, an ancilla system will have to be introduced by either Alice or Bob. It is demonstrated that Alice can perform generalized measurement on the two qubits in her possession to achieve the goal when the knowledge of non-maximal entangled state is available only for her, and physical implementation of generalized measurement implies that an ancilla qubit has to be introduced by Alice. Recognizing that classical communication (CC) is neither free nor noiseless, we exploit the impact of noisy classical communication on quantum teleportation. It is demonstrated that the noisy classical communication will decrease the success probability of completing mission, and the success probability can be improved when more bit of classical communication is permitted. An inequality for success probability is further obtained when classical communication is less than L bits where L is a positive number. We also exploit quantum teleportation problem when the knowledge of entangled state is not exact or when the inexact projective measurement is available. In both cases it is impossible to implement exact quantum teleportation, but robust analysis indicates that quantum teleportation may be acceptable if the knowledge of entangled state is good enough. Furthermore, we can obtain some inequalities for fidelity of what Alice planned to send and what Bob obtained actually. Finally, it is underlined that some open problems including robust quantum system identification should be further explored.