QuILT Day
Monday, March 25, 2019

MEETING ROOM

All lectures will be held in Rm 407 ("Dougie Hitt" room) on the fourth floor of Earl K. Long Library (UNO Main Library). A projector and a small whiteboard (5 feet wide and 3 feet high) are available for presentations.

PROGRAM

Monday

9:00–9:30	Lior Cohen — Encoding and decoding of photon states in polarization and picosecond time bin
9:30–10:30	Michael Mislove — Semantic models for quantum programming languages
10:30–11:00	Coffee Break (coffee shop on 1st floor of library)
11:00–11:30	Noah Davis — Simulating and evaluating the coherent Ising machine
11:30–12:00	Denys Bondar — Uncountability of quantum control: A connection of Diophantine equations with quantum control problems
12:00–13:30	Lunch Break (food court near library)
13:30–14:00	Eneet Kaur — Asymptotic security of discrete-modulation protocols for continuous-variable quantum key distribution
14:00–14:30	Gerard McCaul — Classical influence functionals
14:30–15:00	Wenlei Zhang — Generating multi-mode entanglement using four-wave mixing
15:00–15:30	Coffee Break (coffee shop on 1st floor of library)
15:30–16:00	Jacob Leamer — Density matrix minimization
16:00–16:30	Sumeet Khatri — Extendibility of quantum states
16:30–17:00	Omar Magaña-Loaiza — Quantum random walks with looped trajectories of light

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ABSTRACTS
(in alphabetical order by speaker surname)

Speaker: **Denys Bondar** (Tulane University)
Title: *Uncountability of quantum control: A connection of Diophantine equations with quantum control problems*
Abstract: Diophantine equations, polynomial equations with integer coefficients and integer unknowns, are among the most important objects in number theory, and they are related to a rich variety of conjectures, including the celebrated Riemann hypothesis. We show how solving these equations can be formulated as optimal control of physical quantum systems. Using this correspondence, we formulate an NP-complete control problem involving only two displacement operators. A connection of quantum control problem with Riemann hypothesis is formulated. A particular implication of our finding is that the negative resolution of Hilbert's tenth problem physically implies that quantum control problems are not algorithmically solvable in general.

Speaker: **Lior Cohen** (Louisiana State University)
Title: *Encoding and decoding of photon states in polarization and picosecond time bin*
Abstract: We introduce a two-qubit information system, realized by two degrees of freedom of a single photon: polarization and time. The photon arrival time is divided into two time-bins representing a qubit, while its polarization state represents a second qubit. The time difference between the two time-bins is created without an interferometer at the picosecond scale, which is much smaller than the detector's response time. The two physically different DOF are analyzed simultaneously by photon bunching between the analyzed photon and an ancilla photon. Full two-qubit states encoded in single photons were reconstructed using quantum state tomography, both when the two DOF were entangled and when they were not, with fidelities higher than 96%.

Speaker: **Noah Davis** (Applied Research Laboratories)
Title: *Simulating and evaluating the coherent Ising machine*
Abstract: Physical annealing techniques present methods for taking advantage of qubits without the need for universal quantum computers. Particularly, annealing systems may offer calculation speed-ups for certain NP-hard optimization problems such as the Max-Cut problem and the Sherrington-Kirkpatrick model. Among promising annealing systems, the coherent Ising machine (CIM) has demonstrated particular potential for solving dense examples of these problems. A CIM uses classical measurement and feedback to couple the degenerate optical parametric oscillators which make up its logical qubits. We use the master equations governing this measurement-feedback system to simulate an idealized (but still classically controlled) CIM on a high performance computing cluster. We present an analysis of this simulation and compare it to experimental instances of CIMs along with other popular annealing methods.

Speaker: **Eneet Kaur** (Louisiana State University)
Title: *Asymptotic security of discrete-modulation protocols for continuous-variable quantum key distribution*
Abstract: We consider discrete-modulation protocols for continuous-variable quantum key distribution (CV-QKD) that employ a modulation constellation consisting of a finite number of coherent states and that use a homodyne-detection receiver. We establish a security proof for arbitrary collective attacks in the asymptotic regime, and we provide a formula for an achievable secret-key rate. Previous works established security proofs for Gaussian-modulation CV-QKD protocols or for discrete-modulation protocols with two

or three coherent states. The main constituents of our approach include approximating a complex, isotropic Gaussian probability distribution by a finite-size Gauss-Hermite constellation, applying entropic continuity bounds, and leveraging previous security proofs for Gaussian-modulation protocols. As an application of our method, we calculate secret-key rates achievable over a pure-loss bosonic channel. Our results indicate that in the high-loss regime the achievable key rates scale optimally, i.e., proportional to the channel's transmissivity, and approach that achieved by a Gaussian-modulation protocol as the constellation size is increased.

Speaker: **Sumeet Khatri** (Louisiana State University)
Title: *Extendibility of quantum states*
Abstract: The k-extendibility problem is to determine if a given bipartite quantum state can be symmetrically extended to several copies of one of the parties. k-extendible states can be used to approximate the set of separable states, and their study is related to the monogamy of entanglement. The k-extendibility problem is also a special case of the quantum marginal problem. In this talk, I will discuss these connections to k-extendibility in detail. I will also provide some currently known results about the k-extendibility of certain classes of quantum states.

Speaker: **Jacob Leamer** (Tulane University)
Title: *Density matrix minimization*
Abstract: Most of the physical properties of a quantum mechanical system can be determined by the eigenvalues of the density matrix describing it. Unfortunately, for systems of interest, the density matrix is often of an extremely high dimensionality, which means that the straightforward calculation of the eigenvalues is prohibitively expensive in terms of computation. While a number of methods have been developed to more efficiently determine these eigenvalues, many of them fail to preserve the properties of the density matrix (i.e. positivity or preservation of the trace) without additional processing. To overcome these deficiencies, we seek to develop a density matrix minimization method that inherently respects these properties without sacrificing the efficiency or accuracy of established methods.

Speaker: **Omar Magaña-Loaiza** (Louisiana State University)
Title: *Quantum random walks with looped trajectories of light*
Abstract: TBA

Speaker: **Gerard McCaul** (Tulane University)
Title: *Classical Influence Functionals*
Abstract: In the study of open quantum systems, influence functionals have proven themselves an invaluable tool, producing otherwise unobtainable analytical results. The influence functional expresses the effect of an environment on an open system exactly, without reference to the environment itself. We present here a classical analogue to the influence functional, and explore some of its properties. The classical influence functional is then used to rigorously derive a generalised Langevin equation from a microscopic Hamiltonian. In this method stochastic terms are not identified heuristically, but instead arise from an exact mapping only available using path-integral formalisms. This derivation highlights the utility of influence functionals, and the power of Hilbert space representations of classical dynamics.

Speaker: **Michael Mislove** (Tulane University)
Title: *Semantic models for quantum programming languages*
Abstract: Our work focuses on semantic models for high level functional quantum programming languages, and in particular how to incorporate support for recursion in such models. I'll begin with some background on semantic models for classical languages, and the results one aims for in such models - soundness and completeness. I'll then describe how quantum circuits can be brought into the picture. Our work was inspired by Rios's and Selinger's language Proto-Quipper-M, a finitary circuit description language for quantum programs, to which we showed how support for recursion could be added. These models are based

on Benton's work on linear / nonlinear models for the lambda calculus, to which an enriched structure has been added to define recursion. Circuit description languages allow the user to define circuits and print the result, count the number of gates, etc., but there is no support for executing the result. For that, dynamic lifting is needed, which in the quantum setting means adding measurements. That remains future work. This is joint work with Bert Lindenhovius (Tulane) and Vladimir Zamdzhiev (LORIA, France, formerly Tulane).

Speaker: **Wenlei Zhang** (Tulane University)
Title: *Generating multi-mode entanglement using four-wave mixing*
Abstract: In this work, we consider a dual-pump setup for generating multi-mode entanglement using four-wave mixing in warm atomic vapor. We derive, in the Fock basis, the output state for vacuum inputs, which we term coupled three-mode squeezed vacuum. We present results of intensity and quadrature squeezing between different combinations of modes. We then investigate the entropy of entanglement of the reduced density operators. We also show that this coupled three-mode squeezed vacuum state can be genuinely tripartite entangled by tuning the squeezing parameters.