QEC07 Poster Information

Bishop, C. Allen

Quantum Computing in a Qutrit Decoherence-free Subsystem

Southern Illinois University Carbondale

The interest in decoherence-free, or noiseless subsystems (DFS/NSs) of quantum systems is both of fundamental and practical interest. Their practical importance stems from the fact that DFSs are useful for protecting quantum information in quantum cryptography and quantum computing systems. Here we discuss transformations which are compatible with a decoherence-free two-state system composed of physical three-state systems. The transformations are compatible with the DFS in the sense that they do not take logical states outside of the DFS/NS during the transformation.

Bremner, Michael

Noise in Globally Controlled Quantum Computers

University of Bristol

There are a number of proposals for quantum computation that require precise control over a global system Hamiltonian. For instance, quantum simulation models which are based on manipulating always on Hamiltonians and those that use translation-invariant spin chains. In some physical systems this style of control is desirable as it can be physically difficult to create one- and two-qubit gates. However one consequence of using globally controlled Hamiltonians to perform computations is that control errors are not necessarily localized to some small subset of qubits. In this presentation we examine the problem of noise generated by inaccuracies in global control parameters. We illustrate the problem by deriving error maps due to imprecise global control for the class of Hamiltonians that generate diagonal unitary operations. We examine how the process fidelity of such control operations varies with the degree of classical control over the system and contrast this with locally controlled architectures. Finally we discuss how the consequences of global control errors can vary between different quantum computing models.

Chen, Xie

Teleportation Depth as a Measure of Gate Complexity for Fault-Tolerant Quantum Computation

MIT

Teleportation, as a computational primitive, is a crucial element providing universal quantum computation to fault-tolerant schemes based on stabilizer codes (arXiv:0706.1382). With universality, we can approximate any gate to arbitrary accuracy, but the space, time, and entanglement resource requirements for such "gate teleportation" primitives is largely unknown. We study this problem using the C_k hierarchy of unitary operations introduced by Gottesman and Chuang, and employ the subset of semi-Clifford gates that take at least one maximal belian subgroup of the n-qubit Pauli group to another maximal abelian one. This allows us to explicitly find the form of a subset of C_k gates for which the complexity of teleportation can be characterized, giving meaning to a measure we call teleportation depth the average number of teleportation steps needed to implement a given gate. For classical circuits, a similar measure of gate complexity, such as the minimal number of Toffoli gates required for construction, is typically intractable. Surprisingly however, the teleportation depth of semi-Clifford C_k gates is found to be bounded. We also present examples of teleportable gates beyond the semi-Clifford or even the C_k framework, which have a bounded teleportation depth . These results call for a complete understanding of the C_k structure for the practical implementation of optimal fault-tolerant quantum computer architectures.

Cholascinski, Mateusz

Fault-Tolerant State Engineering with Topological Phases of Geometric Origin

Adam Mickiewicz University

We discuss geometric transformations generated by traversing a path in a control parameter space around domains of strongly enhanced Berry's field. This fictitious field can be easily determined for quantum systems in which transformations are of purely geometric (as opposed to dynamical) origin. The analogy to the original Aharonov-Bohm scenario enables quantitative judgment of fault-tolerance in selected experiments. We compare the influence of both geometric and dynamical contribution to the decoherence and determine conditions in which the geometric transformations are intrinsically fault-tolerant.

Crosswhite, Gregory

Matrix Product States: An Excalibur in the Quest for a Self-Correcting Quantum Memory

University of Washington

One of the holy grails of quantum error correction theory is to design a practical self-correcting memory: a physical system which is naturally robust against loss of quantum information, and so needs no active error correction process. This can be thought of as looking for a new phase of matter which allows one to store quantum information in a bulk of material, analogous to how the ferromagnetic phase is used to store classical information. Unfortunately, this phase has proven elusive because it is likely to involve a great deal of entanglement, and so is located in a regime where current methods such as mean field theory break down. If we were studying small systems, we could use direct numerical simulation in the computational basis to handle this entanglement; however, for the large systems in which we are interested this is simply infeasible due to the exponential amount of storage needed. Instead, our hope lies in models which allow one to incorporate a sufficient amount of entanglement in large systems to allow this phase to emerge, while remaining small enough to be tractable on current hardware. In my poster, I will present two such models, matrix product states (1D) and projected entangled-pair states (2+D), which have garnered much interest over the last decade due to their ability to capture important characteristics of large systems featuring entanglement. I will show how these models can be applied to simulate physical systems using a local variational algorithm. Finally, I will present current results from our group of using these techniques.

Cunha, Marcelo Terra

The Geometry of Entanglement Sudden Death

UFMG - Brazil

In open quantum systems, entanglement can vanish faster than coherence. This phenomenon is usually called sudden death of entanglement. In this talk/poster sudden death of entanglement is discussed from a geometrical point of view, in the context of two qubits. A classification of possible scenarios is presented, with important known examples classified. Theoretical and experimental construction of other examples is suggested as well as large dimensional and multipartite versions of the effect are discussed.

Darabad, Robabeh Rahimi

Quantum Wipe Effect for Coherence Conservation

Kinki University

We introduce an effect of decoherence conservation caused by a very high rate of dissipation of an environmental system coupled with a main system. A very high rate of dissipation in the environmental system does not give enough time to absorb information from the main system. This effect is not included in the well-known effects of noise suppression, such as Zeno effect, bang-bang control, or decoherence-free subspace.

Elliott, Matthew B.

One-Way Quantum Computation using Faulty Cluster States
University of New Mexico
We study how heralded qubit losses during the preparation of a two-dimensional cluster state, a universal resource state for one-way quantum computation, affect its computational power. Above the percolation threshold we present a polynomial-time algorithm that concentrates a universal cluster state, using resources that scale optimally in the size of the original lattice. On the other hand, below the percolation threshold, we show that single qubit measurements on the faulty lattice can be efficiently simulated classically.

Guenda, Kenza

Two Families of Quantum Codes Derived from Cyclic Codes
University of Sciences and Technology Algiers, Algeria
We characterize the affine-invariant maximal extended cyclic codes. Then by the CSS construction, we derive from these codes a family of pure quantum codes. Also for order of q mod n even, a new family of degenerate quantum stabilizer $[[n; 1; \geq sqrtn]]_q$ codes is derived from the classical duadic codes. This answer an open problem asked by Aly et al.

Hayes, Alexander

Fault-Tolerant Protocols for Circuit-Based Linear Optics Quantum Computing
University of Queensland
The prospects for adding general error correction to currently proposed quantum computing systems is currently an area of significant interest in international research. Among these systems, linear optics quantum computing(LOQC) is a strong contender, with photonic qubits possessing desirable properties, such as long decoherence times. Error-correction plays a particularly significant role in LOQC, due to the inherently non-deterministic nature of the entangling gates used in these schemes. This makes it necessary to encode qubits against unwanted measurements; we have chosen to develop schemes that utilise parity encoding [1] to protect the logical qubits. An appealing aspect of computational schemes based on parity encoding is that they are founded in the circuit model of quantum computation. This makes such schemes highly compatible with existing methods of quantum error correction. We take advantage of this compatibility to adapt the parity encoding for use with the circuit-based telecorrector protocol developed by Dawson et. al. [2]. The protocol efficiently applies an error-correcting code (such as the 7-qubit Steane code) to provide tolerance of both depolarizing and loss errors.

Isailovic, Nemanja

Throughput-Optimized Ancilla Factories
University of California, Berkeley
We propose a design for an "ancilla factory" in ion trap technology which generates a constant stream of encoded ancilla qubits for use in a quantum computer maximizing throughput of error free qubits. We present our toolset for the automated synthesis layout and scheduling of ancilla factories for various coding and ancilla prep schemes. We then use the bandwidths of these factories to determine the resources needed to provide encoded ancillae at a rate at which they could be consumed by the rest of the circuit in order to remove encoded ancilla generation from the critical path. We perform this analysis for ancilla-intensive fault tolerance procedures like postselection in circuits such as error-corrected memory cells and a quantum ripple carry adder. We finally study the ion needs for ancilla qubits given aggressive ion reuse.

Karasik, Raisa

Multi-Particle Decoherence Free Subspaces in Extended Systems
UC Berkeley
A decoherence-free subspace (DFS) is a collection of states that is immune to the dominant noise effects created by the environment. DFS is usually studied for states involving two or more particles and is considered a prominent candidate for quantum memory and quantum information processing. We prove that a perfect physical DFS requires co-located particles,

i.e., the Dicke limit. The assumptions made are very general and invoke a homogeneous environment with energy-conserving coupling to the particles. We indicate when a DFS outside the Dicke limit may be possible; this includes molecular and confined systems.

Li, Yunfan

Encoded Dynamical Recoupling with Shaped Pulses

University of California, Riverside

Encoded Dynamical Recoupling is a passive error correction technique which can be used to enhance the performance of a quantum error correcting code (QECC) when decoherence is dominated by low-frequency modes. The elements of the stabilizer group are applied in the decoupling cycle which makes the encoded logical operations fault-tolerant. We studied the effectiveness of this technique both analytically and numerically for several three- and five-qubit codes, with decoupling sequences utilizing either Gaussian or self-refocusing pulse shapes. When logical pulses are intercalated between the decoupling cycles, the technique is effective in canceling constant perturbation terms, but its performance is much weaker in the presence of a time-dependent perturbation simulated as a classical correlated noise. The decoupling accuracy is substantially improved if logical pulses are applied concurrently with the decoupling, as long as certain adiabaticity condition is satisfied.

Looi, Shiang Yong

Construction of Codes Saturating Singleton Bound

Carnegie Mellon University

Using graph states, it is possible to construct a large class of distance 2 codes saturating the quantum Singleton bound. This result can also be generalized to non-binary codes.

Lopez, Cecilia

Efficient Error Characterization in Quantum Information Processing

NSE, MIT

We describe how to use the fidelity decay as a tool to characterize the errors affecting a quantum information processor through a noise generator G_τ. For weak noise, the initial decay rate of the fidelity proves to be a simple way to measure the magnitude of the different terms in G_τ. When the generator has only terms associated with few-body couplings, our proposal is scalable. We present the explicit protocol for estimating the magnitude of the noise generators when the noise consists of only one and two-body terms, and describe a method for measuring the parameters of more general noise models. The protocol focuses on obtaining the magnitude with which these terms affect the system during a time step of length τ; measurement of this information has critical implications for assessing the scalability of fault-tolerant quantum computation in any physical setup.

Musumbu, Dibwe Pierrot

Application of Quantum Walk to Stochastic Process

University of KwaZulu-Natal

One-dimensional turbulent fluid flow is studied with classical and quantum random walks on graphs. The mixing time of the random walks and the distribution function of the process are evaluated. We explore and compare the impact of graph expanders on the optimizization of the sampling on both classical and quantum random walks.

Quiroz, Gregory

Soft-Pulse Dynamical Decoupling in a Cavity

USC

Dynamical decoupling is a coherent control technique where the intrinsic and extrinsic couplings of a quantum system are effectively averaged out by application of specially designed driving fields (refocusing pulse sequences). This entails pumping energy into the system, which can be especially dangerous when it has sharp spectral features like a cavity mode close to resonance. In this work we show that such an effect can be avoided with properly constructed refocusing sequences. To this end we construct the average Hamiltonian expansion for the system evolution operator associated with a single "soft" pi-pulse. To second order in the pulse duration we characterize a symmetric pulse shape by three parameters wo of which can be made zero by shaping. We express the effective Hamiltonians for several pulse sequences in terms of these parameters and use the results to analyze the structure of error operators for controlled Jaynes-Cummings Hamiltonian. When errors are canceled to second order numerical simulations show excellent qubit fidelity with strongly-suppressed oscillator heating.

Sarvepalli, Pradeep Kiran

Operator Quantum Error-Correcting Codes via Clifford Codes

Texas A&M University

Operator quantum error-correcting codes promise to bring quantum error-correction a little closer to practice by affording simpler error recovery schemes. In this talk we present a method to construct these codes from Clifford codes, which are a generalization of the stabilizer codes. An important consequence of this construction is that these codes can be constructed from any classical code removing the restriction of self orthogonality (which is needed for stabilizer codes). We also discuss bounds on the parameters of these codes and the trade offs with respect to (MDS) stabilizer codes.

Shaw, Bilal

Encoding One Logical Qubit Into Six Physical Qubits

University of Southern California

We discuss several methods to protect a qubit against single-qubit errors by encoding it into six physical qubits. We first present a degenerate six-qubit quantum error-correcting code. We explicitly present the stabilizer generators, codewords, logical Pauli operators, and logical CNOT operator for this code. We then prove that a six qubit code cannot simultaneously possess a Calderbank-Shor-Steane stabilizer and correct against arbitrary single-qubit errors. We finally construct a non-degenerate entanglement-assisted six-qubit quantum error-correcting code that uses one extra bit of entanglement shared between the sender and the receiver. We discuss the advantages and disadvantages for each of our six-qubit quantum error-correcting codes.

Taghavi, Soraya

Linear Operator Quantum Error Correcton

USC

This is a generalized theory of Operator Quantum error correction which applies to any linear map. This scheme combines the recently developed theory of Linear Quantum error correction with the noiseless subsystem method to arrive at a general model that includes the known techniques as special cases.

Valente, Diego

Improving Intrinsic Decoherence in Multi-Quantum-Dot Charge Qubits

University of Central Florida

We discuss decoherence in charge qubits formed by multiple lateral quantum dots in the framework of the spin-boson model and the Born-Markov approximation. We consider the intrinsic decoherence caused by the coupling to bulk phonon modes. Two distinct quantum dot configurations are studied: (i) Three quantum dots in a ring geometry with one excess electron in total and (ii) arrays of quantum dots where the computational basis states form multipole charge configurations. For the three-dot qubit, we demonstrate the possibility of performing one- and two-qubit operations by solely tuning gate voltages. Compared to the proposal by DiVincenzo

it et al. involving a linear three-dot spin qubit, the three-dot charge qubit allows for less overhead on two-qubit operations. For small interdot tunnel amplitudes, the three-dot qubits have Q factors much higher than those obtained for double dot systems. The high-multipole dot configurations also show a substantial decrease in decoherence at low operation frequencies when compared to the double-dot qubit.

Van Meter, Rodney

Distributed Quantum Error Correction

Keio University

The recent discovery of the use of operator subspaces as a generalization of stabilizers for quantum error correction (QEC) has provided a more flexible framework for the implementation of QEC. We have analyzed implementation of one such code, the Bacon-Shor code, in a two-dimensional memory layout where operations on one axis are substantially more expensive and error-prone that on the other, such as node-local versus inter-node operations in a distributed system. By favoring stabilizers that use local operations, rather than long-distance operations, we solve a key problem in the implementation of a quantum multicomputer with code words spanning multiple nodes. We also show efficient distributed creation of the cat states necessary for syndrome calculation. This work improves the prospects for the use of very small nodes, holding only a few physical qubits each.

Zeng, Bei

Codeword Stabilized Quantum Codes

Massachusetts Institute of Technology

Quantum error correction codes play a central role in quantum computation and quantum information. While considerable understanding has now been obtained for a broad class of quantum codes, almost all of this has focused on stabilizer codes, the quantum analogues of classical additive codes. However, such codes are strictly suboptimal in some settings—there exist nonadditive codes which encode a larger logical space than possible with a stabilizer code of the same length and capable of tolerating the same number of errors. There are only a handful of such examples, and their constructions have proceeded in an ad hoc fashion, each code working for seemingly different reasons. We present a unifying approach to quantum error correcting code design, namely, the codeword stabilized quantum codes, that encompasses additive (stabilizer) codes, as well as all known examples of nonadditive codes with good parameters. In addition to elucidating nonadditive codes, this unified perspective promises to shed new light on additive codes as well. Our codes are described by two objects: First, the codeword stabilizer that can be taken to describe a graph state, and which transforms the quantum errors to be corrected into effectively classical errors. And second, a classical code capable of correcting the induced classical error model. With a fixed stabilizer state, finding a quantum code is reduced to finding a classical code that corrects the (perhaps rather exotic) induced error model. We use this framework to generate new codes with superior parameters ((n,K,d)) to any previously known, the number of physical qubits being n, the dimension of the encoded space K, and the code distance d. In particular, we find ((10,18,3)) and ((10,20,3)) codes. We also show how to construct encoding circuits for all codes within our framework.