FM 60: Quantum Computation: Fault Tolerance & Error Correction

Time: Wednesday 14:00–16:00 Location: 3044

Invited Talk FM 60.1 Wed 14:00 3044

Scalable Quantum Error Correction with the Bosonic GKP Code — •Barbara Terhal — TU Delft, The Netherlands

We review the bosonic GKP (Gottesman-Kitaev-Preskill) code which encodes a qubit into an oscillator and its possible implementation in a microwave mode in circuit-QED hardware. We discuss how GKP code states can be created from Schroedinger cat states or from a dispersive interaction with a qubit. We propose a scalable architecture which uses a surface code on top of the GKP qubits. For a noise model of Gaussian stochastic displacement errors, we discuss how to decode such toric-GKP code and give estimates for the threshold standard deviation, corresponding to a low (4 or more) number of average photons in the GKP code states.

FM 60.2 Wed 14:30 3044

Twins Percolation for Qubit Losses in Topological Color Codes — Davide Vodola[1], •David Amaro[1], Miguel Angel Martin-Delgado[2], and Markus Müller[1] — [1]Department of Physics, Swansea University, Singleton Park, Swansea SA2 8PP, United Kingdom — [2]Departamento de Fisica Teorica I, Universidad Complutense, 28040 Madrid, Spain

In our work [1] we establish and explore a new connection between quantum information theory and classical statistical mechanics by studying the problem of qubit losses in 2D topological color codes. We introduce a protocol to cope with qubit losses, which is based on the identification and removal of a twin qubit from the code, and which guarantees the recovery of a valid three-colorable and trivalent reconstructed color code. Moreover, we show that determining the corresponding qubit loss error threshold is equivalent to a new generalized classical percolation problem. We numerically compute the associated qubit loss thresholds for two families of 2D color code and find that with $p = 0.461 \pm 0.005$ these are close to satisfying the fundamental limit of 50% as imposed by the no-cloning theorem. Our findings reveal a new connection between topological color codes and percolation theory, show high robustness of color codes against qubit loss, and are directly relevant for implementations of topological quantum error correction in various physical platforms.

[1] D. Vodola, D. Amaro, M. A. Martin-Delgado, and M. Müller, Phys. Rev. Lett. **121**, 060501 (2018)

FM 60.3 Wed 14:45 3044

recent trends with the AdS/CFT correspondence in the tensor network setting — •Matthew Steinberg[1,2] and Javier Prior[3] — [1]HQS Quantum Simulations — [2]FU Berlin — [3]Politechnical University of Cartagena

In recent years, much attention has been drawn to possible connections between the much-lauded theory of quantum gravity, the AdS/CFT correspondence, and quantum information theory. A natural setting for the study of bulk-boundary correspondences has developed with tensor network methods. These methods, and in particular MERA and perfect tensor networks, have been compared to the AdS/CFT correspondence and partially realize certain aspects of the duality. Hyperinvariant tensor networks have since been proposed in previous work as one model that links both previously described classes of tensor networks. This model, although promising, admittedly faces several challenges that impede an algorithmic realization of hyperinvariant tensor networks. In this talk, we wish to review some of these developments and offer insights into future study of the AdS/CFT correspondence in the tensor network setting. Our hope is that our present work will stimulate interest in hyperinvariant tensor networks in the theoretical community.

FM 60.4 Wed 15:00 3044

Robustness of Magic and Symmetries of the Stabiliser Polytope — •Markus Heinrich and David Gross — Institute for Theoretical Physics, University of Cologne

We give a new algorithm for computing the robustness of magic - a measure of the utility of quantum states as a computational resource. In the magic state model of fault-tolerant quantum computing, non-Clifford operations are effected by injecting non-stabiliser states, which are referred to as magic states in this context. The robustness of magic measures the complexity of simulating such a circuit using a classical Monte Carlo algorithm. It is closely related to the degree negativity that slows down Monte Carlo simulations through the infamous sign problem. Surprisingly, the robustness of magic is sub-multiplicative. This implies that the classical simulation overhead scales subexponentially with the number of injected magic states - better than a naive analysis would suggest. However, determining the robustness of n copies of a magic state involves a costly convex optimisation problem in a 4^n-dimensional space. We make use of inherent symmetries to reduce the problem to n dimensions, leading to a runtime which is super-polynomially faster than previously published methods. This allows us to compute the robustness of up to 10 copies of the most commonly used magic states. Guided by the exact results, we find a finite hierarchy of upper bounds to the robustness where each level can be evaluated in polynomial time. Technically, we use symmetries of the stabiliser polytope to connect the robustness of magic to the geometry of a low-dimensional convex polytope.

FM 60.5 Wed 15:15 3044

The Clifford group, Howe duality and quantum codes — •Felipe Montealegre-Mora and David Gross — University of Cologne, Cologne, Germany

The Clifford group is a central object in the theory of quantum fault-tolerance. It has also been on the spotlight in the mathematics community, because of its connections to the representation theory of symplectic group and Howe duality. In particular, the following questions have become relevant: how do tensor-power representations of the Clifford group decompose and what are their invariants? Here we answer these questions: all sub-representations live in certain self-orthogonal CSS codes. These representations arise from embeddings of lower-order tensor-powers of the Clifford group into the larger tensor-power representation. Our work has implications in Howe duality over finite fields. Furthermore, it may be seen as a generalization of the result that the invariants of the Clifford group are self-dual codes.

FM 60.6 Wed 15:30 3044

On the Second-Order Asymptotics of the Partially Smoothed Conditional Min-Entropy & Application to Quantum Compression — Dina Abdelhadi and •Joseph M. Renes — Institute of Theoretical Physics, ETH Zürich

Recently, Anshu et al. introduced "partially" smoothed information measures and used them to derive tighter bounds for several information-processing tasks, including quantum state merging and privacy amplification against quantum adversaries [arXiv:1807.05630 [quant-ph]]. Yet, a tight second-order asymptotic expansion of the partially smoothed conditional min-entropy in the i.i.d. setting remains an open question. Here we establish the second-order term in the expansion for pure states, and find that it differs from that of the original "globally" smoothed conditional min-entropy. Remarkably, this reveals that the second-order term is not uniform across states, since for other classes of states the second-order term for partially and globally smoothed quantities coincides. By relating the task of quantum compression to that of quantum state merging, our derived expansion allows us to determine the second-order asymptotic expansion of the optimal rate of quantum data compression. This closes a gap in the bounds determined by Datta and Leditzky [IEEE Trans. Inf. Theory 61, 582 (2015)], and shows that the straightforward compression protocol of cutting off the eigenspace of least weight is indeed asymptotically optimal at second order.

FM 60.7 Wed 15:45 3044

Performance Estimator of Codes On Surfaces — •Ciaran Ryan-Anderson — Swansea University, Swansea, United Kingdom

This work discusses the Python package called Performance Estimator of Codes On Surfaces (PECOS). PECOS serves as a framework for studying, developing, and evaluating quantum error-correcting codes (QECCs).

The package attempts to balance usability, functionality, and simplicity. PECOS uses an object-oriented approach to represent basic concepts used to describe and evaluate quantum error-correcting protocols as classes. The classes are highly extendable and can be easily replaced by custom classes developed by the user.

PECOS also boasts an implementation of a new stabilizer simulation algorithm that was developed concurrently with the package PECOS. This stabilizer simulator gives an average square-root speedup for topological stabilizer codes (TSCs) over previous stabilizer simulation algorithms. Stabilizer simulators allow stochastic error models that can apply errors beyond Pauli errors such as Clifford errors and measurement-like errors. Thus, the new stabilizer simulation algorithm, implemented in PECOS, greatly reduces the runtime of Monte Carlo simulations of such error models for TSCs and other similar QECCs.

It is hoped that PECOS will serve as a useful tool in studying and evaluating QEC protocols and encourage code reuse and transparency in the QEC community.