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Title: The smallest quantum error correcting codes for amplitude damping noise

Abstract:
Quantum error correction (QEC) plays a critical role in preventing information loss in quantum systems and provides a framework for reliable quantum computation. However, implementing protocols for QEC and fault tolerance remains a challenge in the current era of noisy, intermediate-scale quantum (NISQ) processors. Here, we discuss recent progress in identifying resource-efficient strategies for QEC, which are tailored for the dominant noise processes affecting the quantum hardware.

Focussing on the amplitude damping noise channel, which affects the coherence (T1) times of superconducting and ion-trap qubits, we describe the smallest quantum error correcting (QEC) code — a 3-qubit code — that corrects up to first order in the damping strength. We generalize this construction to create a family of codes that corrects amplitude damping noise up to any fixed order. We formalise the fundamental connection between the structure of our codes and the noise structure via a relaxed form of the Knill-Laflamme QEC conditions, that are different from the existing formulations. Although the recovery procedure for this code is non-deterministic, our codes are optimal with respect to overheads and outperform existing codes to tackle AD noise, in terms of entanglement fidelity. Our modified framework for approximate QEC leads us to a new classes of quantum codes tailored to AD noise and also gives rise to a noise-adapted quantum Hamming bound.

Reference: arXiv:2410.00155