
Quantum Error Correction and Related Topics
Correction d'erreurs quantiques et sujets connexes
(Org: **David Kribs** and/et **Rajesh Pereira** (University of Guelph))

SERGE ADONSOU, University of Guelph

Unified and Generalized Approach to Entanglement-Assisted Quantum Error Correction

We introduce a framework for entanglement-assisted quantum error correcting codes that unifies the three original frameworks for such codes called entanglement-assisted quantum error correction, entanglement-assisted operator quantum error correction, and entanglement-assisted classical enhanced quantum error correction under a single umbrella. The unification is arrived at by viewing entanglement-assisted codes from the operator algebra quantum error correction perspective, and it is built upon a recently established extension of the stabilizer formalism to that setting. We denote the framework by entanglement-assisted operator algebra quantum error correction, and we prove a general error correction theorem for such codes, derived from the algebraic perspective, that generalizes each of the earlier results. This leads us to a natural notion of distance for such codes, and we derive a number of distance results for subclasses of the codes. We show how the classically enhanced codes form a proper subclass of the entanglement-assisted subspace codes defined by the general framework. We identify and construct new classes of entanglement-assisted subsystem codes and entanglement-assisted hybrid classical-quantum codes that are found outside of the earlier approaches, and we include a quantum communication application.

NINGPING CAO, National Research Council Canada

Quantum Error-Corrected Non-Markovian Metrology

Quantum metrology aims to maximize measurement precision on quantum systems, with a wide range of applications in quantum sensing. Achieving the Heisenberg limit (HL)—the fundamental precision bound set by quantum mechanics—is often hindered by noise-induced decoherence, which typically reduces achievable precision to the standard quantum limit (SQL). While quantum error correction (QEC) can recover the HL under Markovian noise, its applicability to non-Markovian noise remains less explored. In this work, we analyze a hidden Markov model (HMM) in which a quantum probe, coupled to an inaccessible environment, undergoes joint evolution described by Lindbladian dynamics, with the inaccessible degrees of freedom serving as a memory. We derive generalized Knill-Laflamme conditions for the HMM and establish three types of sufficient conditions for achieving the HL under non-Markovian noise using QEC. Additionally, we demonstrate the attainability of the SQL when these sufficient conditions are violated, by analytical solutions for special cases and numerical methods for general scenarios. Our results not only extend prior QEC frameworks for metrology but also provide new insights into precision limits under realistic noise conditions.

GUILLAUME DAUPHINAIS, Xanadu Quantum Technologies

ALEXANDER FREI, University of Waterloo

SARAH HAGEN, University of Illinois at Urbana-Champaign

Quantum Secret Sharing with Three and Four Qubits

Quantum replacer codes correct for errors in which the state of one subsystem is replaced, and the location of the error is known. A secret sharing code refers to the special requirement that all possible replacer errors may each be corrected. We

build on our previous work deriving general conditions met by any quantum replacer codes to completely characterize quantum secret sharing codes for three and four qubits. Additionally, we introduce helper codes as a relaxation of the conditions of a general secret sharing code. Instead of being able to correct errors in all locations, only some errors may be corrected with use of a non-erasable party referred to as the helper. This inequality between qubits of a code can be experimentally motivated.

SOOYEONG KIM, University of Guelph

Quasiorthogonality of Commutative Algebras and Implications for Quantum Information

The notion of quasiorthogonality for operator algebras was introduced to provide a quantitative measure of the geometric relationships between algebras. Pivotal to the development and motivation for considering quasiorthogonality were applications in quantum information theory. We deepen the theory of quasiorthogonal operator algebras through an analysis of the commutative algebra case. We give a new approach to calculate the measure of orthogonality between two such subalgebras of matrices, based on a matrix-theoretic notion we introduce that has a connection to complex Hadamard matrices. We also show how this new tool can yield significant information on the general non-commutative case.

ANDREW NEMEC, University of Texas at Dallas

Entanglement-Assisted Subspace Codes

We show how entanglement-assisted codes can be constructed from arbitrary quantum codes by sending correctable subsets to the receiver ahead of time. In the case of degenerate codes, we show that the shared entanglement can be reduced. We also give examples of permutation-invariant EA codes, the first EA codes outside of the codeword-stabilized framework.

MUKESH TAANK, University of Guelph

Generalized Knill–Laflamme theorem for families of isoclinic subspaces

Isoclinic subspaces have been studied for over a century. Quantum error correcting codes were recently shown to define a subclass of families of isoclinic subspaces. The Knill–Laflamme theorem is a seminal result in the theory of quantum error correction, a central topic in quantum information. We show there is a generalized version of the Knill–Laflamme result and conditions that applies to all families of isoclinic subspaces. In the case of quantum stabilizer codes, the expanded conditions are shown to capture logical operators. We apply the general conditions to give a new perspective on a classical subclass of isoclinic subspaces defined by the graphs of anti-commuting unitary operators. We show how the result applies to recently studied mutually unbiased quantum measurements (MUMs), and we give a new construction of such measurements motivated by the approach.