SEMINARIO

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A characterization of binary CSS-T quantum codes

Abstract: To guard against decoherence, the development of quantum computing requires error correction. This can be done by encoding the physical qubits with a quantum error-correcting code (QECC). One of the main problems with this approach is obtaining QECCs that implement the desired operations on the logical qubits. Particularly interesting are implementations that only involve transversal gates on the physical qubits since they naturally mitigate the proliferation of errors. However, due to the Eastin–Knill theorem, it is not possible to find a QECC that implements a universal gate set transversely.

A common strategy to circumvent this limitation is to consider codes that implement the Clifford group transversely, and then perform magic state distillation to apply a logical non-Clifford gate, usually the T gate, which requires a code implementing T transversely. With this motivation, CSS-T were introduced in [2]. These are CSS codes which support a transversal T gate. This is weaker than requiring the code to implement T transversely on the logical qubits, but studying these codes gives good candidates for codes that may implement logical non-Clifford operations.

In [1] we obtain an alternative condition to characterize when a pair of classical codes gives rise to a CSS-T code:

$$(C_1, C_2) \text{ is a CSS-T pair if and only if } C_2 \subset C_1 \cap (C_1^{\star 2})^{\perp},$$

where $C_1^{\star 2}$ is the componentwise product of C_1 with itself. This allows us to define a partially ordered set of CSS-T pairs, and study some of its properties. In particular, we obtain a propagation rule for CSS-T codes. With our alternative characterization, we can determine the CSS-T pairs that can be constructed with cyclic codes in terms of their defining sets. By considering cyclic and extended cyclic codes, and using our propagation rule, we obtain CSS-T pairs with better parameters than those in the current literature.

[1] E. Camps-Moreno, H. H. López, G. L. Matthews, D. Ruano, R. San-José, and I. Soprunov. An algebraic characterization of binary CSS-T codes and cyclic CSS-T codes for quantum fault tolerance. Quantum Inf. Process., 23(230), 2024.

[2] N. Rengaswamy, R. Calderbank, M. Newman, and H. D. Pfister. On optimality of CSS codes for transversal T. IEEE J. Sel. Areas Inf. Theory, 1(2):499–514, 2020.

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