Quantum Computing PHYS-541, Project 9

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Stabilizer quantum error correction codes and fault tolerance

After having introduced the basic aspects of quantum error correction codes (QECC), we have studied the stabilizer formalism, which allows defining a general class of QECCs systematically. We have additionally discussed the ideas behind fault-tolerant quantum computing and provided an elementary proof of the threshold theorems.

The goal of this project is to review the topic of stabilizer QECCs and of fault tolerance. In particular:

1. Read and understand the parts on stabilizer codes and on fault tolerance, and present them. You may refer to Daniel Gottesman's PhD thesis or to this review article.

2. Implement a simple three-qubit repetition code on the QASM simulator (don't use the built-in library for this purpose). This code only protects against X errors. Implement in particular a circuit that encodes a single qubit onto the three-qubit code, and a circuit that decodes the three-qubit code into one qubit. Then carry out a single qubit operation X transversally on the code and check that the decoded result corresponds to what expected.

3. Concatenate now this QECC onto itself, in order to obtain a nine-qubit QECC. Compute the probabilities of a logical qubit flip on the three-qubit and on the nine-qubit codes, starting from the probability p of a physical bit flip. On the basis of this calculation, compute the threshold of this simple QECC.

4. Simulate now an error by applying X gates to physical qubits. Show that the concatenated QECC can correct up to two X errors in the same group of three qubits, as per design of the concatenated code.