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ES170 Narang

Final Project Report

**Quantum Error Correction**

Our scope as described in our initial proposal is as follows, based on the paper “Quantum Error Correction for Beginners,” by Devitt et. al.

1. Implement in QISKit and characterize a 3-qubits circuit that encodes and corrects for a single 𝜎x error. Analyzing the hardware mapping on IBM Q.
2. Implement in Qiskit and characterize (along with analyzing the hardware mapping on IBM Q) a 9-qubits circuit for a single-qubit encoding with Shor’s Single Qubit Quantum Error Correction code.
   1. Implement a Z-error correction circuit using the 9-qubits circuit.
   2. Implement a X-error correction circuit using the 9-qubits circuit.
   3. Implement a S-error correction circuit using the 9-qubits circuit.
   4. Implement a T-error correction circuit using the 9-qubits circuit.
3. Experiment with implementing a 18-qubits 2-qubits encoding circuit and use them on a 3-qubits Deutsch-Jozsa circuit to demonstrate the absence of error in the qubits state.

At this point, we have completed the first task by implementing a 3-qubit circuit that corrects a bit flip on at most one qubit. As we saw in lecture, this circuit does so by using ancillary qubits to identify (with high probability) which qubit was flipped. The error can then be corrected by applying an X or NOT gate to the flipped qubit. As we learned, correcting for a phase flip is similar to correcting for a bit flip. The only difference is that first both data qubits are transformed to the Hadamard basis so that instead of determining a bit flip, applying a CNOT to the ancilla qubit determines a phase flip. We tested error correcting both bit flips and phase flips with 3 qubits. After implementing this circuit in QISKit, we were also tried run it on IBM Q and visualize the results but we are having some issues doing so. Hopefully with more time we will be able to run this circuit on IBM Q and test some values.

Our goal in the initial stages of this project was to better understand error correction and the scope of our project. We all read the paper “Quantum Error Correction for Beginners” as well as sections of the chapter on quantum error correction in Mike & Ike. This has given us a better conceptual understanding of quantum error correction and how larger, more complex circuits can be constructed to deal with multiple errors or combinations of the various types of errors (bit flip, phase, etc.) on multiple qubits.

Unfortunately, due to a combination of midterms, other final projects, penultimate/ultimate problem sets, and preparation for final exams, the three of us have not been able to spend much time at all on our project so far. We definitely want to tackle more of the scope and will aim to at least implement the 5-qubit and 9-qubit circuits outlined in “Quantum Error Correction for Beginners.” After implementing these, we will also run them on IMB Q and hopefully be able to compare the results. This should give us a baseline from which to attempt implementing error correction with the Deutsch-Jozsa algorithm.