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Final Project Proposal

**Quantum Error Correction**

*Motivation:*

Quantum error correction is a cutting-edge field of research within the field of quantum computing. is used in [quantum computing](https://en.wikipedia.org/wiki/Quantum_computer) to protect [quantum information](https://en.wikipedia.org/wiki/Quantum_information) from errors due to [decoherence](https://en.wikipedia.org/wiki/Decoherence) and other quantum noise. Accurate error correction is vital if we are to achieve usable large-scale quantum computers and employ quantum algorithms across multiple qubits.

Classical error correction is based on the principles of redundancy. This means that the information is stored multiple times (a “code”) so if noise corrupts some part of this code then it is more likely that the original information can be recovered. However, there are some problems that differentiate quantum from classical error correction, the most important of which is the no-cloning theorem. This postulates that quantum information cannot be copied, and thus we cannot use the concept of classical redundancy for quantum error correction.

In both classical and quantum error correction, a state (of information) is mapped to an encoded state by a series of transformations. Classical error correction is based on syndrome measurements of this encoded state (once an error is identified, the appropriate corrective operation is applied and the original information is extracted). Quantum error correction is also based on syndrome measurements, however they cannot reveal anything about the encoded state itself because quantum measurement results in collapse. Therefore quantum syndrome measurements only tell us which qubit has been corrupted and how, not what state the qubit was in. A beautiful result is that most arbitrary noise effects can be expressed as a superposition of the error basis (made up of the Pauli matrices X, Y, Z and the identity matrix I). In other words, the ability to correct the depolarizing channel implies the ability to correct an arbitrary single qubit operation.[[1]](#footnote-0)

*Procedure:*

1. Identify a quantum correction algorithm that could be implemented on a quantum simulator on a classical computer.
2. Characterise the nature of the implementation of the algorithm.
3. Identify potential improvements that could be made to the algorithm.
4. Identify whether and how the algorithm could be implemented on existing hardware, such as the IBMQX5, QS1\_1 or Regetti’s hardware.

*Scope:*

The following is derived from a paper on quantum error correction.[[2]](#footnote-1)

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.

1. *Quantum Computation and Quantum Information* by Nielsen and Huang. [↑](#footnote-ref-0)
2. “Quantum Error Correction for Beginners” by Devitt et al.

   <https://arxiv.org/pdf/0905.2794.pdf> [↑](#footnote-ref-1)