Quantum Weirdness: Exploring Quantum Error Correction

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Progress

Channel Creation with IBM Quantum

I created an IBM Quantum channel and set up an environment to execute quantum circuits. This included accessing real quantum hardware and simulators.

3-Bit Repetition Code Implementation

I started the implementation of the basic 3-bit repetition code that will address bit-flip errors, the steps I need to do are:

- **Encoding:** Encode a single logical qubit into three physical qubits using CNOT gates.
- **Detect Noise:** After using IBM's quantum hardware, identify noise, specifically pauli-X, or, bit-flip errors.
- **Decoding:** Used majority voting to correct errors and recover the logical state.
- **Testing:** Test the circuit in both noiseless (simulated) and noisy environments using Qiskit Runtime.

Demonstrating Gates

I explored the properties of quantum gates, focusing on:

- The **Hadamard gate**, which places a qubit into superposition.
- The **CNOT gate**, used for entangling qubits and constructing error correction codes.

Noise Models

I originally planned to incorporate noise models in Qiskit to simulate real-world imperfections, but opted for real noise through using quantum hardware (thanks to qiskit runtime):

Challenges Encountered/Will Encounter

- Understanding the interplay between bit-flip errors and quantum superposition states proved challenging, particularly when applying error correction.
- The introduction of Qiskit Runtime required adjustments to the circuit execution workflow.
- Visualizing noise effects on the Bloch sphere and interpreting results in a meaningful way I foresee taking a significant effort.

To-Do List

- Extend the project to include **Shor's Code** for correcting both bit-flip and phase-flip errors if there is time.
- Compare the performance of the 3-bit repetition code and Shor's Code on real quantum hardware.
- Develop visual aids for the report and presentation, including:
  - Histograms comparing error rates with and without error correction.
  - Bloch sphere animations demonstrating error effects and recovery.
- Finalize the report with detailed results, including metrics such as logical qubit recovery rates and fidelity.