Quantum Error Correction

Qubit Bit-Flip and Phase-Flip Error Correction

Abdul Fatah Jamro

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In this article, We consider quantum error correction. Perticularly, We describe bitflip error in quantum computing and correct it using qiskit python.

1 Introduction

Qubit is very fragile in nature. It is valnurable to decoherence and noise. Qubit mainly come across with two type of errors bit-flip and phase-flip errors. We can correct qubit errors by quantum error correction techinques. Bit-flip error can be corrected using quantum circuit called bit flip code.

2 Bit flip error

Bit flip error is such an error in which a bit is flipped from one state to its opposite state. For instance 0 flips to 1 state $0- > 1$ In quantum circuit, We use 3 qubits, one logical qubit and two ancillary (extra) qubits.

3 Bit flip circuit

We encode the logical qubit by (entangling) applying control NOT $CXorCNOT$ gate with other two ancillary qubits. This process is also called encoding. After encoding if main qubit or logical qubit is flipped we repeat the process of applying CNOT gates just like mirroring the encoding process. This mirroring is also called decoding. At the end a taffoli gate is applied that is control-control-NOT gate CCX This circuit is called bit flip error correcting circuit. This circuit of 3 qubits has capacity to correct the error if one qubit is flipped only. It can not correct the qubit if more than one qubits are flipped.

4 Phase-flip error

In quantum circuit Phase-flip error occurs that changes the phase of qubit from 1 to -1 and from + to -. This error correction also require three qubits to make one qubit phase error free. Bit flip and phase flip error correction circuits are differen.

5 Phase-flip circuit

For enconding part Logical qubit (qubit one) is applied control-NOT gate with second and third qubit. Then all three qubits are kept in superposition or + state by applying Hadamard (H) gate. while decoding circuit is mirrored of encoding part and applied toffoli gate at the end. In this way, Phase-flip error of one qubit can be correct.

6 note

Quantum circuits for bit-flip and phase-flip are different.

7 Python code

Python code of this quantum circuit is written and availbe in jupyter notebook file in this repository.