Quantum Computing: Implementing Grover’s Algorithm on IBM Q

Eric Li, Maziar Farahzad, Tzu-Chieh Wei

Physics Department, C.N. Yang Institute for Theoretical Physics

The purpose of this project was to implement Grover’s search algorithm for a small number of qubits on the IBM Q Experience. IBM Q offers three public-access quantum computers, from 5 qubits to 16 qubits, and quantum computer simulators. We accessed IBM Q through the Quantum Information Science Kit (QISKit) via Jupyter Notebook in Python programming language. Quantum computers are the future of technology; for example, they can run computations much faster, even exponentially faster, than their classical counterparts for certain tasks. These machines utilize quantum-mechanical phenomena to gain this added power such as superposition, the ability of a qubit to be multiple distinct states simultaneously. Grover’s algorithm is a quantum search algorithm requiring only$ O(\sqrt{N}) $runtime in contrast to classical computers requiring$ O(N)$ runtime, achieving quadratic speedup. Although this speedup is not exponential, search algorithms are an essential function in many applications and thus it is quite useful. It operates in two parts: the first marks the amplitude of the item being searched for negative and the second does an inversion about the mean amplitude. To implement Grover’s algorithm searching on 3-qubit circuits, I first learned the 2-qubit implementation through literature and IBM Q’s Experience Documentation. Then, we created a circuit to run Grover’s algorithm for 3-qubits. We utilized a series of Toffoli, Hadamard, and X logic gates to construct the quantum circuit. While both the 2-qubit Grover simulation and actual run returned clean results, only the 3-qubit simulation returned a high (0.953) probability of obtaining$ |111〉$. The data from IBM’s 5-qubit quantum computer gave only a 0.271 probability of obtaining$ |111〉$. This was due to noise--environmental disturbances which perturb the coherence of the qubits; further research should focus on mitigating the effects of noise. This work was supported by the Simons Foundation and the National Science Foundation.