Quantum Computation

Tutorial

Dr S. S. Chandra

A Quantum Computer uses qubits and the principles of quantum theory, such as superposition of states, in place of regular digital bits to do computations. The result is a computer that produces non-deterministic computational output, where there is a finite probability that you have arrived at your desired correct answer. But it also allows for the simultaneous computation of all possible branches for a given number of qubits. This enables certain problems that are nearly impossible on conventional computers to become tractable on a quantum computer, as well as improve the performance of certain problems such as the Deutsch oracle problem.

Problem 1

Describe and illustrate the form of the wavefunction in quantum theory. Discuss its properties and how it explains most of the major principles of quantum theory.

[Hint: See Lecture 1 and 2 of the Quantum Computation module]

Problem 2

Describe how qubits are constructed, including the principles used in their construction with the appropriate mathematical expressions, comparisons to classical bits with the same notation, as well as the advantages that are offered by them with respect to computation.

[Hint: See (Moore and Mertens, 2011) section 15.2 and the Microsoft Quantum Computing for CS Video]

Problem 3

Draw the quantum circuits for the four main types of operations of a two qubit system including the conditional NOT gate and verify each operation using matrix multiplication on appropriate example quantum states.

[Hint: See (Moore and Mertens, 2011) section 15.2 and the Microsoft Quantum Computing for CS Video]

Problem 4

Describe why a quantum computer is well suited and offers advantages over conventional computers for the Deutsch problem.

[Hint: See (Moore and Mertens, 2011) section 15.4 and the Microsoft Quantum Computing for CS Video]

Problem 5

Discuss the advantages and disadvantages of quantum computing as compared to classical computing. Making sure to provide an explanation of the quantum mechanics principles, its unique computational features and why quantum computers have the potential to outperform classical computers.

References

Moore, C., Mertens, S., 2011. The Nature Of Computation. Oxford University Press.