Quantum Computation

Tutorial

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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 its construction with the appropriate mathematical expressions, comparisons to a classical bit with the same notation, as well as the advantages that are offered by it with respect to computation.

[Hint: See Lecture 3 of the Quantum Computation module, (Moore and Mertens, 2011) section 15.2.2 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 Lecture 3 and 4 of the Quantum Computation module, (Moore and Mertens, 2011) section 15.2.7 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 Lecture 4 and 5 of the Quantum Computation module, (Moore and Mertens, 2011) section 15.4.1 and the Microsoft Quantum Computing for CS Video]

References

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