Simulating Large Quantum Circuits using Cloud Computing

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Simulating large quantum circuits using classical computers is a difficult and important task. It often arises as a key preproduction step in efforts to construct quantum hardware with tens, hundreds, and even thousands of physical (non-error-corrected) qubits. For example, there is a need to better understand the behaviour of noisy quantum devices with 10-50 qubits in order to scale the technology further. This is typically done through a combination of physical experiments and classical simulations. Meanwhile, some quantum algorithms preclude analytic study even when performed upon error-free logical qubits. Estimations of their resource scaling, and the general design of algorithms beyond current limitations, requires emulating a perfect device. Therefore, classical simulation of quantum devices is an essential tool to advance both experimental and algorithmic research in quantum computing.

State vector simulations of quantum circuits is a popular approach. Because it keeps track of the entire state vector of a quantum circuit, it is rather memory intensive, even for relatively small numbers of qubit. As a result, state-vector simulations of circuits with more than 40 qubits require the use of high-performance computing resources.

Here we use the Quantum Exact Simulation Toolkit (QuEST), an open-source quantum simulator which hybridizes MPI and OpenMP to accelerate simulation on high performance computing systems. We simulate random quantum circuits of up to 44 qubits using QuEST on AWS Cloud. Cloud computing is emerging as a robust, efficient, and affordable computational solution to address complex problems for the scientific community. One of the benefits of cloud computing is the possibility of deploying virtual clusters with different architectures within minutes to meet the requirements of different applications and workflows. AWS offers an open-source management tool called ParallelCluster that helps to deploy and manage high performance computing cluster in the AWS Cloud. In this work, we present how to run quantum circuit simulations up to 44 qubits using QuEST on AWS Cloud. In particular we show how we have deployed the underlying HPC architecture and how QuEST has been used to experiment with quantum random circuit simulation.

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