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Efficient quantum circuit simulation using tensor networks

Quantum circuit simulations on classical computers are essential to develop better quantum computers and algorithms. Even more when there are few noisy and small quantum computers available. Different approaches have been proposed to simulate quantum circuits such as full amplitude-vector evolution, Feynman paths, decision diagrams or tensor networks.

We can simulate a quantum circuit by contracting its tensor network. This task has an exponential cost in general, but in many cases it can be performed much more efficiently. One immediate challenge is to find an efficient contraction ordering of tensors in the network. Finding an optimal ordering is a NP-hard problem, but there are some methods and heuristics to find near optimal orderings in many cases.

The goal of this work is to improve an open source quantum circuit simulator, QXTools [1], written in Julia and developed as part of the QuantEx Project. It is based on tensor network methods and is capable of scaling on pre-Exascale and Exascale compute platforms. We benchmarked six contraction ordering algorithms, [2], using a collection of quantum circuits including Grover's, QFT, Random Quantum Circuits and QAOA. Our experimental results show that Tamaki's algorithm [3] offers the best results in most cases when we increase the number of qubits. We plan to include some new ordering algorithms in the QuantEx framework. Besides, we intend to include the possibility of launching in parallel several ordering algorithms in order to choose the best result to simulate any given quantum circuit.

References

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