Contribution ID: **98** Type: **Short Talk**

Quantum Gate Pattern Recognition and Circuit Optimization for Scientific Applications

Thursday, 20 May 2021 10:50 (13 minutes)

There is no unique way to encode a quantum algorithm into a quantum circuit. With limited qubit counts, connectivities, and coherence times, circuit optimization is essential to make the best use of near-term quantum devices. We introduce two separate ideas for circuit optimization and combine them in a multi-tiered quantum circuit optimization protocol called AQCEL. The first ingredient is a technique to recognize repeated patterns of quantum gates, opening up the possibility of future hardware co-optimization. The second ingredient is an approach to reduce circuit complexity by identifying zero- or low-amplitude computational basis states and redundant gates. As a demonstration, AQCEL is deployed on an iterative and efficient quantum algorithm designed to model final state radiation in high energy physics. For this algorithm, our optimization scheme brings a significant reduction in the gate count without losing any accuracy compared to the original circuit. Additionally, we have investigated whether this can be demonstrated on a quantum computer using polynomial resources. Our technique is generic and can be useful for a wide variety of quantum algorithms.

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Session Classification: Quantum Computing

Track Classification: Offline Computing