Routing quantum circuits with AlphaZero deep exploration

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Compiling a quantum circuit for specific quantum hardware is a challenging problem, since current quantum processing units generally have low connectivity between physical qubits and limited coherence time. To maximize the utilization of limited resources and guarantee the executability of any arbitrary quantum circuit on the target hardware, a circuit transformation minimizing depth overhead is necessary. Due to the large, combinatorial search space for such circuit transformations, coupled with a high branching factor, existing algorithms for higher qubit numbers tend to conduct only superficial searches, often resulting in solutions with a large optimality gap.

Our method combines two frameworks: firstly, a transformer network trained via Monte Carlo Tree Search (MCTS) proposes mappings at each layer of the quantum circuit; secondly, a routing method based on graph matchings realizes these proposed mappings. This hybrid approach ensures strategic mappings while guaranteeing consistent and deterministic routing through an algorithm that finds optimal routing sequences for a grid architecture. Alternatively for an arbitrary qubit topology, the transformer network can directly place SWAP gates.

The MCTS is guided by a transformer neural network, allowing for deeper searches and potentially better solutions than existing heuristic algorithms, such as SABRE. We present benchmarks comparing our method to other algorithms, demonstrating its performance in finding better (shorter) solutions.

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