Cover Letter
CSE60876
Ruiyang Qin
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Improve quantum computing performance via quantum gate decomposition

Paper 1: Towards Optimal Topology Aware Quantum Circuit Synthesis
2020 IEEE International Conference on Quantum Computing and Engineering (QCE)

General Topic: Compile arbitrary unitaries into a sequence of gate native to a quantum processor

Specific Behavior or Activity: The authors define what is the problem and why an efficient gate decomposition is necessary. Then, they chose two platforms to conduct experiments. We can think of the two platforms are two quantum computers with different structures. They use their method to optimize many quantum algorithms which run on the two quantum computers. The goal is to show their method can improve wide quantum algorithms and the method work well with different quantum computers.

Research Questions: Quantum (NISQ) Devices era, which is characterized by design space exploration at small qubit scale, together with a need for highly optimized implementations of circuits. To foster adoption, tools need to overcome some of the currently perceived shortcomings: ● Synthesis generates deep circuits ● Synthesis does not account for hardware topology ● Synthesis is slow

Challenges: The common way to build circuits is adding basis gates. The problem of this method is that the depth of circuit will keep increasing. The deeper the circuits, the more noise and less efficiency of the circuit.

Paradigm: The authors investigate the existing hardware implements and SOTA works. The explain what is the limitation, why the limitation should be solved in priority, and what factors contribute to the limitation.

Problems: The authors don’t directly state the problems, so I conclude their words into three points. The whole paper aims to solve the problem which is constricted by the three points. How to generate the circuit which satisfies the following conditions: Expressibility should be max; Error-tolerance should be max; Use gates as less as possible and the depth of circuit should be limited

Importance: “First, the data dispels the concern that synthesis produces deep circuits.”, “Second, to our knowledge we provide the first practical demonstration of topology aware synthesis that does not significantly increase circuit length.”

Claims: “Overall, we believe our results are very encouraging and show the general applicability of quantum circuit synthesis techniques during the NISQ decade(s).” The authors claim: “Better numerical optimizers” and “Better parallelization of the search algorithm”

State of Knowledge: The existing work called Universal Q, which performs same task but not as good as the authors do

Evidence: For various algorithms and decomposition tasks, there are different hardware settings, this work proform on these benchmarks and compare the performance with the UQ

Story Structure: In this paper, the authors first explain the problem they want to study. Then they explained the motivation and the necessary background. Later on, they explain the method they proposed and how to implement it. Then, they show the experiment result and the scenarios to perform the experiment. In the end, they show the future use of their method.

Paper 2: Expressibility and entangling capability of parameterized quantum circuits for hybrid quantum-classical algorithms
2019 Advanced Quantum Technologies

General Topic: How to estimate whether a quantum circuit is appropriate for the hardware and algorithm is a valuable thing to study. It's also important to define the appropriate metrics to estimate that. This paper works on that.

Specific Behavior or Activity: They first use many examples from existing works to show what's lacking. They state that there is a lack of general understanding and intuition behind characteristics associated with an "effective" training circuit. They also provide a very detailed example to show the problem they study. Later on, they present two metrics they come up with. They apply their metrics into various experiments/benchmarks to show the improvement.

Research Questions: Given two circuits A and B, which circuit is more suitable for a given application and why? Are there figures-of merit, or more neutrally, descriptors we can compute for these circuits to approach such questions?

Challenges: Parameterized quantum circuits play an essential role in the performance of many variational hybrid quantum-classical (HQC) algorithms. One challenge in implementing such algorithms is to choose an effective circuit that well represents the solution space while maintaining a low circuit depth and number of parameters.

Paradigm: They bring up the research questions following the failings of existing works and they use an example to illustrate the research questions. The research questions can be generalized to all scenarios similar to the example.

Problems: " there remains a lack of understanding on what makes a particular parameterized circuit more powerful or useful than another."

Importance: "While these devices cannot perform errorcorrected, large scale quantum computations, smaller but meaningful computations are anticipated to find use by combining both quantum and classical computational resources.", "A particular class of algorithms that maximizes the use of such pre-threshold hardware is the hybrid quantumclassical (HQC) algorithm, which strategically divides computational tasks between quantum and classical resources.”. Basically, HQC is important for quantum computing being practical use, and robust descriptors is the key to implement good HQC

Claims: “we presented a theoretical framework to characterize and compare parameterized quantum circuits, independent of the algorithm or application.”, “ We described how the rate of saturation and the saturated value may be useful indicators of the performance of a parameterized quantum circuit may help to design and select such circuits in an application.”, “we applied the descriptors to identify useful circuit fragments, in terms of both the gate choice and the configuration of two-qubit operations.”

State of Knowledge: Expressibility and entanglement haven’t been studied through. Different from many research areas of CSE, quantum computing is a new area. People are trying to set rules and study what’s appropriate for quantum computing. This work gets decent attentions and has more than 300 citations, which is hugh in quantum computing. It’s not published in a traditional top conference but its value is beyond what we can imagine.

Evidence: The authors present various experiments. Their methods is a “helper”, which can be used to many algorithms. They just compare the performance between with and without their methods

Story Structure: The authors first explain what is the issue and why the issue is important and should be solved. Then the authors use many practical examples to support their statements. Later on, they present their methods. Importantly, they perform tons of experiments to demonstrate their work. Since their work is a foundation work, which will be used by many upper level works, they need to perform wide-ranged experiments to show the robustness and reliability of their work