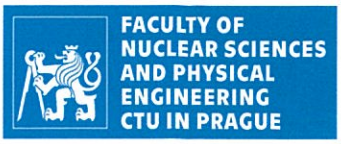
Bachelor Thesis Report



Name of the Student: Vlastimil Hudeček

Title of the thesis: Programming quantum computers

Grade: A (excellent)

9 January 2023

Detailed Report

The thesis involves a detailed study of hybrid quantum-classical algorithms mainly quantum approximation optimization algorithm (QAOA) and variational quantum eigensolver (VQE) that can be executed on noisy intermediate-scale quantum (NISQ) devices and its applications. It also outlines the currently available quantum software tools for the development of quantum algorithms on the quantum computers and presents basic implementation of QAOA and VQE for simple problem on Qiskit software development kit (SDK). Overall the thesis gives a complete insight into the QAOA and VQE algorithms and its applications.

The thesis starts with a brief introduction to the basic concept of quantum computation and algorithms. It almost covers all the basic tools needed to understand quantum computers and quantum algorithms. Other than few minor incoherence in the writing, the introduction to the concept of quantum computing reaches its goal.

Chapter 2 of the thesis contains the details on QAOA algorithm and it is explained with an example of max-cut problem. With the help of max-cut problem, it is shown that by maximizing the approximation ratio of the graph,

the maximum bipartition of any graph can be found. But here few things are not very clear since the Table 2.4 shows that for D>3, quantum and classical approximation of <C> is same which doesn't shows any advantage of quantum over classical algorithm. Similarly Eq. (2.2.2) misplaces the brakets. But the chapters captures the complete picture of QAOA algorithm.

Similarly, Chapter 3 of the thesis contains complete picture of VQE algorithm. VQE minimizes the expectation value of target Hamiltonian with the help of a unitary operator. Thesis outlines the various steps to find the minimum expectation of the target Hamiltonian and it explains various components of VQE with the help of an example of ab-initio molecular Hamiltonian. Various encoding methods have also been described to encode the state of the molecular system along with the measurement optimization strategies that reduces the circuit repetitions. The study also shows various methods of quantum circuit parameterization for state preparation and its optimization. But in my opinion the chapter ends very abruptly without any conclusion. A small conclusion or a discussion on the concept of VQE would help one to get the overall picture of the whole chapter which contains various optimization strategies, encoding methods and parameterization schemes.

Chapter 4 of the thesis gives an outline of the quantum programming languages and instruction sets available for performing quantum algorithms by various groups and industries. But it mostly focuses on Qiskit SDK developed by IBM research department. Qiskit has the advantage of accessing the physical quantum hardware in the IBM Quantum project via the IBM Cloud and for the rest of the project Qiskit has been used for realizing QAOA and VQE algorithm.

Chapter 5 involves the implementation of simple problems based on QAOA and VQE algorithm on quantum circuit with the help of Qiskit. The thesis does a good job on utilizing the quantum tools available on the public platforms by the IBMs cloud. It also helps one to get a better understanding of quantum circuit and the how it is different from classical. In this chapter, various other applications of QAOA and VQE is also discussed. In my opinion the discussion on shortcomings of the present day quantum computer and sources of the error could have been elaborated to get a clear picture. But none the less, it covers all the aspects of the its main focus which is QAOA and VQE.

Finally, the thesis does a good job in studying QAOA and VQE algorithms. It also talks about the quantum SDKs and its use in realizing the QAOA and VQE on quantum hardware. Overall, it is a very good start for someone who is interested in quantum computation and algorithms.

Name of the reviewer:

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