World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:18, No:03, 2024

An Evolutionary Approach for QAOA for Max-Cut

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Abstract : This work aims to create a hybrid algorithm, combining Quantum Approximate Optimization Algorithm (QAOA) with an Evolutionary Algorithm (EA) in the place of traditional gradient based optimization processes. QAOA's were first introduced in 2014, where, at the time, their algorithm performed better than the traditional best known classical algorithm for Max-cut graphs. Whilst classical algorithms have improved since then and have returned to being faster and more efficient, this was a huge milestone for quantum computing, and their work is often used as a benchmarking tool and a foundational tool to explore variants of QAOA's. This, alongside with other famous algorithms like Grover's or Shor's, highlights to the world the potential that quantum computing holds. It also presents the reality of a real quantum advantage where, if the hardware continues to improve, this could constitute a revolutionary era. Given that the hardware is not there yet, many scientists are working on the software side of things in the hopes of future progress. Some of the major limitations holding back quantum computing are the quality of qubits and the noisy interference they generate in creating solutions, the barren plateaus that effectively hinder the optimization search in the latent space, and the availability of number of qubits limiting the scale of the problem that can be solved. These three issues are intertwined and are part of the motivation for using EAs in this work. Firstly, EAs are not based on gradient or linear optimization methods for the search in the latent space, and because of their freedom from gradients, they should suffer less from barren plateaus. Secondly, given that this algorithm performs a search in the solution space through a population of solutions, it can also be parallelized to speed up the search and optimization problem. The evaluation of the cost function, like in many other algorithms, is notoriously slow, and the ability to parallelize it can drastically improve the competitiveness of QAOA's with respect to purely classical algorithms. Thirdly, because of the nature and structure of EA's, solutions can be carried forward in time, making them more robust to noise and uncertainty. Preliminary results show that the EA algorithm attached to QAOA can perform on par with the traditional QAOA with a Cobyla optimizer, which is a linear based method, and in some instances, it can even create a better Max-Cut. Whilst the final objective of the work is to create an algorithm that can consistently beat the original QAOA, or its variants, due to either speedups or quality of the solution, this initial result is promising and show the potential of EAs in this field. Further tests need to be performed on an array of different graphs with the parallelization aspect of the work commencing in October 2023 and tests on real hardware scheduled for early 2024.

Keywords : evolutionary algorithm, max cut, parallel simulation, quantum optimization
Conference Title : ICGEC 2024 : International Conference on Genetic and Evolutionary Computation
Conference Location : Miami, United States
Conference Dates : March 11-12, 2024