JPMC Challenge: Performance improvement of Quantum Optimization Package QOkit

Statement: Optimization problems arising in many scientific and business areas today can be difficult to solve even with modern fastest supercomputers. The advent of quantum computers offers a potential resolution to some of these computational challenges in terms of improved quality, speed, cost, and applicability of solutions. For example, in finance, quantum optimization algorithms can be applied to find the optimal set of assets or financial instruments to obtain the highest returns under given risk constraints, a problem commonly known as Portfolio Optimization (PO). One of the leading proposals to improve optimization using quantum computing is the quantum approximate optimization algorithm (QAOA). It is important to analyze the performance of QAOA to design experiments that can show an advantage over classical optimization algorithms. For instance, since the performance of QAOA increases with circuit depth, it is important to simulate high-depth QAOA. While a theoretical analysis of QAOA is hard, we often resort to numerical techniques to understand its performance, which requires scaling the simulations to large systems using high-performance computers.

JPMC Global Technology team has developed QOKit, a fast QAOA simulator that can run on a range of platforms from single-core CPU to a CPU/GPU cluster. A novel pre-compute step enables QOKit to speed up QAOA simulations by up to 7 times. A simple performance benchmark of QOKit is available here.

Since QAOA is a combination of many algorithmic and computational steps, there can be many uncovered avenues to further improve its performance. The challenge of this Hackathon topic is performance improvement on QOKit in any of the following, including but not limited to, ways:

- Speedup on a single-core CPU
- Improve or propose a better scaling strategy for large CPU/GPU cluster
- Improve initial states and/or mixers for portfolio optimization.

See an example notebook here

References:

1. QOKit paper: https://arxiv.org/pdf/2309.04841

2. QOKit GitHub repository: https://github.com/jpmorganchase/QOKit/tree/main

3. Examples: https://github.com/jpmorganchase/QOKit/tree/main/examples

4. Performance Benchmark:
https://github.com/jpmorganchase/QOKit/blob/main/examples/benchmark.ipynb

5. Example of using QOKit for Portfolio optimization:
https://github.com/jpmorganchase/QOKit/blob/main/examples/QAOA_portfolio_optimization.ipynb