Quantastox

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Practical Portfolio Optimization with Warm-Starting Qubits using QAOA

The title may sound like a mouthful, but I will go through each piece step by step. For a more technical description and the source code, please follow the Jupyter Notebook here.

If link does not work, please direct your web browser to https://github.com/RoyalWeden/QHack-PortfolioOptimization/blob/main/portfolio.ipynb.

1. Portfolio Optimization Overview

The problem I am solving is portfolio optimization on stock data provided by Yahoo Finance. The purpose of portfolio optimization is to determine which stocks to invest in, while maintaining a certain budget, reducing risk, and maximizing potential reward. This is done with the expected returns of each asset (stock), as well as the matrix that compares the correlation of each stock with one another (whether they both increase/decrease at the same time or increase and decrease at opposite times). This information helps to determine which stocks you should be invested in to increase returns, while reducing risk by minimizing to put all of your eggs into one basket.

To give the investor the greatest level of flexibility, I provide the option of changing the following factors:

- Risk Factor – how big of a risk the investor is willing to take.
- Budget – the $$$ amount the investor is willing to use to invest in stocks.
- Stock Tickers – which stocks (i.e. AAPL, GOOG, TSLA, etc.) the investor would like to invest in.
- Minimum Spending – the $$$ amount the investor wants to spend at the minimum when investing.
- Share Limit – the maximum number of shares the investor would like to buy per stock ticker.

2. Quantum Approximate Optimization Algorithm (QAOA)

To solve Portfolio Optimization an algorithm, or a set of instructions, needs to be determined and used. For this problem I choose the Quantum Approximate Optimization Algorithm. By using all of the variables described previously, this algorithm attempts to find and recommend the most optimal stocks and how many shares of each of those stocks to purchase. QAOA is a quantum algorithm, however, to generate results, a classical optimizer must be used as well. This creates a hybrid quantum-classical algorithm, making it best suited for execution on Noisy Intermediate-Scale Quantum devices that are in use today.

What makes QAOA special compared to classical algorithms is that it uses quantum mechanical properties to find the best solution. As quantum devices have more qubits, this algorithm may be able to optimize for portfolios that current classical hardware is not able to do. Some of the quantum mechanical properties QAOA uses is superposition and entanglement. These two properties allow for different pieces of information of the algorithm to be related.

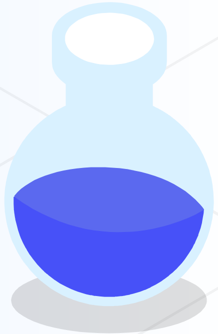
Additionally, QAOA is different compared to other quantum algorithms because it has an approximation ratio to increase the speed of its computing, which is another reason it is used to tackle portfolio optimization. As demonstrated in the Jupyter Notebook, QAOA less than half the time it took to compute another type of optimization algorithm, known as Variational Quantum Eigensolver.

3. Warm-Starting Qubits

Firstly, I will describe a two terms: quadratic programs (QP) and semidefinite programs (SDP). These are essential math problems that have constraints on the variables, in which the variables may be binary, integers, or continuous.

Warm-starting is when the solutions to either of these programs as continuous-valued are used to initialize quantum-classical hybrid algorithms, which, in this case, will be focused on warm-starting QAOA.

After warm-starting QAOA, it can be ran as normal, compared to running the QAOA without warm-starting, the probability of getting the most optimal result will differ. This is because warm-starting QAOA has a much higher probability of sampling the optimal solution, which makes it the perfect choice to use in portfolio optimization when there are many factors in play.



4. Conclusion

With these three key elements, portfolio optimization, quantum approximate optimization algorithm, and warm-starting qubits, an investor can make smart decisions to determine which set of stocks will produce the highest returns with a low risk, all the while diversifying their portfolio. Quantum computing software may be able to show advantage in this space as quantum computers increase the number of qubits to allow for more complex portfolios to be generated.

At the same time, as Google Quantum AI discussed in their paper arXiv:2004.04197, QAOA may not outperform classical optimization today. However, QAOA will continue to be a popular method to benchmark a wide variety of hardware platforms. With the use of warm-starting qubits for QAOA and other possible additions to QAOA, this algorithm may be able to outperform classical optimization for problems like portfolio optimization.

Thank You

I am Michael Kougang, a student at Wayzata High School. I hope you enjoyed to brief, non-technical presentation.