AQC Hack the Horizon - Quantum Finance Challenge Portfolio Optimisation

Background

In traditional finance, portfolio optimisation involves selecting assets to maximize returns while minimising risk. The Markowitz model formulates this as a quadratic optimisation problem. With quantum computing, we can solve these complex optimisation problems more efficiently, especially when dealing with many assets and constraints.

Challenge

You are a quantum finance analyst at Africa Quantum Consortium. The company manages a portfolio of 50 assets and needs to rebalance it weekly. Due to transaction costs and market impact, you can only change a limited number of positions each week.

Objective: Find the optimal set of assets to buy/sell/hold that maximises expected returns while:

1. Staying within risk tolerance limits
2. Minimising transaction costs
3. Maintaining sector diversification constraints
4. Limiting position changes to no more than K assets

Mathematical Formulation

This can be mapped to a Quadratic Unconstrained Binary Optimisation (QUBO) problem:

$$Minimise\text{: } -\sum(u_i * x_i) + \lambda * \sum\left(\sum(\sigma_{ij} * x_i * x_j)\right) + \tau * \sum\left(\left|x_i - x_{i_{prev}}\right|\right)$$

Subject to:

$$-\sum(x_i) = N \; (maintain\ portfolio\ size)$$

$$-\sum(sector_k * x_i) \leq S_{max} \; (sector\ limits)$$

$$-\sum\left(\left|x_i - x_{i_{prev}}\right|\right) \leq K \;\; (max\ position\ changes)$$

Where:

$$\boldsymbol{x_i} \in \{\mathbf{0}, \mathbf{1}\} \qquad (\mathbf{1} = hold/buy, \mathbf{0} = sell/nothold)$$

$$\boldsymbol{\mu_i} = expected\ return\ of\ asset\ \boldsymbol{i}$$

$$\boldsymbol{\sigma_{ij}} = covariance\ between\ assets\ \boldsymbol{i}\ and\ \boldsymbol{j}$$

$$\boldsymbol{\lambda} = \text{ risk aversion parameter}$$

$$\boldsymbol{\tau} = \text{ transaction cost multiplier}$$

$$\boldsymbol{x_{i_{prev}}} = previousposition(0\ or\ 1)$$

Quantum Mapping

Map this to an Ising model Hamiltonian for quantum annealing:

$$H = \sum(h_i * s_i) + \lambda * \sum(J_{ij} * s_i * s_j)$$

where

$$s_i \in \{-1, 1\} \quad relates \quad to.\ \boldsymbol{x_i}\ by\text{: } \boldsymbol{s_i} = \mathbf{2}\boldsymbol{x_i} - \mathbf{1}$$

Dataset:

Expected Output Format

Your solution should provide:

1. Selected assets (list of assets to hold)
2. Transaction list (buy/sell decisions)
3. Expected portfolio return
4. Portfolio risk (standard deviation)
5. Total transaction costs
6. Sector allocation breakdown

Evaluation Criteria

1. Optimality (40%): Quality of solution measured by Sharpe ratio
2. Quantum Implementation (30%): Effective use of quantum/quantum-inspired algorithms
3. Constraint Satisfaction (20%): Adherence to all constraints
4. Innovation (10%): Creative approach to problem solving

Hints

1. Start by simplifying the problem (reduce asset count, relax constraints)
2. Consider Qiskit for quantum annealing/QAOA
3. Classical pre-processing can help reduce problem size
4. Benchmark against classical solutions (ML, Monte Carlo, heuristic algorithms)

Bonus Challenges

1. Implement a real-time rebalancing trigger based on market conditions
2. Add cardinality constraints (minimum positions per sector)
3. Incorporate liquidity constraints based on market cap
4. Create a hybrid quantum-classical solution