

Quantum Algorithms for Portfolio Optimization in Finance

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Abstract—The increasing complexity of financial markets has heightened the demand for advanced computational methods capable of optimizing portfolios under multi-dimensional constraints involving risk, return, diversification, and liquidity. Traditional optimization frameworks, such as mean-variance analysis and heuristic meta-optimization, are limited by their scalability and sensitivity to non-convex, high-dimensional data structures. This study explores the application of quantum algorithms to portfolio optimization, demonstrating how Quantum Approximate Optimization Algorithm (QAOA), Quantum Annealing, and Variational Quantum Eigensolver (VQE) can address computational bottlenecks inherent in classical approaches. Quantum computation offers the potential to encode complex financial systems as Hamiltonian functions, allowing parallel exploration of vast solution spaces through superposition and entanglement. This enables faster convergence toward optimal portfolio allocations while simultaneously accounting for multi-factor correlations and dynamic market conditions. The research further investigates the role of hybrid quantum–classical optimization pipelines, in which quantum solvers perform core optimization tasks while classical systems manage data preprocessing and constraint validation. Empirical modeling and simulation indicate that quantum-based approaches can outperform conventional methods in risk-adjusted return optimization, efficient frontier computation, and real-time portfolio rebalancing. By bridging the gap between quantum computing and financial engineering, this study contributes to the development of next-generation financial analytics systems, aligning with the broader goal of achieving more adaptive, transparent, and data-resilient financial decision-making.

■ Portfolio optimization lies at the core of modern finance, guiding investment strategies by balancing the trade-off between expected return and associated risk [7]. Classical models, such as Markowitz’s mean-variance optimization, form the foundation of quantitative finance but are increasingly inadequate for handling the high-dimensional, non-linear, and stochastic nature of modern financial data. As portfolios expand to include multiple asset classes, derivative instruments, and time-varying constraints, the resulting optimization problems often become

NP-hard, rendering them computationally infeasible for traditional algorithms [8]. This limitation has prompted growing interest in leveraging quantum computing as a transformative tool for financial optimization.

Quantum computing’s inherent ability to represent and process data probabilistically through quantum superposition and entanglement allows it to evaluate a vast number of potential portfolio configurations simultaneously [2]. In the context of finance, this capability can significantly accelerate the identification of global optima in large search spaces where classical algorithms tend to become trapped in local minima [6]. Algorithms such as the Quantum

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