A Comparative Analysis of Quantum-Inspired Algorithms for Solving NP-Hard Problems

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Abstract. In the pursuit of efficient computational solutions for NP-hard problems, quantum-inspired algorithms have emerged as a formidable alternative to traditional heuristics. This study systematically evaluates three quantum-inspired approaches: Quantum Approximate Optimization Algorithm (QAOA), Quantum Annealing, and Variational Quantum Eigensolver (VQE) through a series of benchmark problems. Employing a quantitative comparison metric based on solution accuracy and computational time, our results illustrate that while QAOA demonstrates superior performance in specific scenarios, Quantum Annealing offers heightened scalability. Furthermore, VQE maintains robustness across diverse problem sets, yet lags in optimality at lower dimensions. The findings underscore the importance of context in algorithm selection, paving the way for future research on hybrid computational frameworks.

Keywords: quantum-inspired algorithms, NP-hard problems, Quantum Approximate Optimization Algorithm, Quantum Annealing, Variational Quantum Eigensolver, computational optimization, heuristic methods, performance evaluation, algorithm comparison

Introduction

In recent years, the exponential growth of computational demands across various domains has underscored the pressing need for effective solutions to NP-hard problems, which include a wide array of complex optimization tasks relevant in fields such as operations research, artificial intelligence, and network design. As we approach 2024, traditional methods often fall short due to their inherent computational limitations, prompting researchers to explore novel paradigms that leverage quantum-inspired computing techniques. These methods, which simulate quantum mechanics principles to enhance classical algorithms, show promise in offering superior performance over conventional

heuristics. Among the variety of quantum-inspired algorithms, the Quantum Approximate Optimization Algorithm (QAOA), Quantum Annealing, and the Variational Quantum Eigensolver (VQE) have garnered significant attention. Each approach offers distinct advantages and trade-offs in tackling NP-hard problems, yet comprehensive studies comparing their effectiveness in a rigorous manner remain sparse. This paper aims to fill this gap by providing a multi-faceted evaluation of these competing approaches, offering insights into their operational mechanics and applicability. Our investigation is structured as follows: we first explore the theoretical underpinnings of each algorithm, discussing their relevance and the optimization frameworks they employ. Following this, we detail the experimental setup, including the benchmark problems and performance metrics utilized for evaluation. Subsequent sections present our findings, supported by thorough statistical analysis, followed by a discussion that contextualizes our results within the broader landscape of computational optimization. Finally, we conclude with reflections on the implications of our findings and potential avenues for future research that can build upon our comparative analysis.

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