A Comparative Analysis of Quantum-Inspired Heuristic Methods for Solving Large-Scale Combinatorial Optimization Problems

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Abstract. The increasing complexity of combinatorial optimization problems in various domains necessitates innovative solution approaches. This paper conducts a comparative analysis of quantum-inspired heuristic methods, specifically focusing on their efficacy in tackling large-scale optimization challenges. We employ a robust experimental framework to evaluate the performance of multiple algorithms across standard benchmark problems. Key metrics include convergence speed, solution quality, and computational efficiency. The results reveal that certain quantum-inspired techniques significantly outperform classical approaches, providing not only superior solutions but also reduced processing time. Insights gained from this analysis highlight the critical role of algorithmic design in optimizing combinatorial solutions, paving the way for future advancements in the field of computational intelligence.

Keywords: Combinatorial Optimization, Quantum-Inspired Algorithms, Heuristic Methods, Performance Evaluation, Computational Intelligence, NP-Hard Problems

Introduction

Combinatorial optimization is a crucial area of computer science that deals with optimizing an objective function under a set of constraints defined over a finite discrete structure. As the digital landscape expands, the complexity and scale of these problems have increased significantly, particularly in sectors such as logistics, telecommunications, finance, and artificial intelligence. The capacity to effectively solve large-scale combinatorial optimization problems is paramount for enhancing operational efficiencies and driving innovation across various industries. Quantum computing has emerged as a promising frontier, offering potential advantages over classical computation methods. Quantum-inspired algorithms, which harness principles derived from quantum mechanics, aim to

enhance heuristic approaches for solving NP-hard problems, presenting an alternative to conventional methods that often struggle with scalability and performance. Despite the growing interest in these algorithms, a systematic evaluation comparing their effectiveness with classical heuristics remains underexplored. This paper aims to fill this gap by providing a comprehensive analysis of various quantum-inspired approaches, including their formulation, strengths, and limitations. We will outline a series of benchmark experiments to assess their performance metrics against widely used classical optimization techniques. The findings of this study are expected to contribute significantly to the understanding of quantum-inspired methodologies in the context of combinatorial optimization. Furthermore, we will discuss the implications of our results for future research directions, emphasizing the importance of continued exploration in this dynamic field. The structure of the paper is as follows: Section 2 presents a review of related work; Section 3 details our proposed methodology; Section 4 discusses experimental results; and Section 5 concludes with future research perspectives.

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