Simulated Annealing Using Quantum Inspired Algorithms *

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Combinatorial optimisation problems involve searching for an optimal solution in a finite range of potential candidates, and optimisation is standardly achieved by approximating the optimal solution. TSP and QUBO are two examples of combinatorial optimizations and are considered hard to solve. One optimization method is simulated annealing, a metaheuristic that slowly modifies a single solution space until the local optima is located [1, 2]. Quantum Inspired Annealing is an algorithm that runs on a classical computer and simulates the dynamical evolution of a physical system, using inspiration from quantum mechanics [3, 4].

This work benchmarks the classical simulated annealing with three different quantum inspired simulated annealing algorithms to solve the TSP and QUBO problems, in order to further explore the applicability and suitability of specific algorithms to specific problems. Four different algorithms were chosen for this comparison: Simulated Annealing (SA) - a variation of the classic simulated annealing; Vanilla Quantum Inspired Annealing (VQIA) - which adds qunatum tunneling to the SA [5]; Quantum Inspired Annealing Using Gradient Descent (GD-QIA) - which translates the problem to an Ising model, and the dynamical evolution is replaced with a gradient descent based method [6]; and Coherent Ising Machine Simulator (SimCIM) - which emulates the behavior of the Coherent Ising Machine [7].

All algorithms ran multiple benchmarking datasets for the TSP and QUBO problems. The analysis covered aspects such as convergence speed, time complexity, parameter tuning, generalizability and scalability, memory overhead, and accuracy differences across the problem sets. The evaluation of these strategies revealed significant differences in their performances. For QUBO and small-case TSP problems, the **SimCIM** algorithm showed the best results and efficiently optimized the solutions for both TSP and QUBO. This method demonstrated a consistent ability to find optimal or near-optimal solutions, indicating its potential as a robust choice to solve those problems efficiently. The SimCIM's robustness can be attributed to its sophisticated mechanism that leverages quantum mechanics principles to find the shortest possible route, therefore presenting itself as a potentially powerful tool in this computational problem space. However, its memory requirements prevented it from solving bigger TSP problems. **SA**

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** Supervised by Prof. Tommie Meyer (University of Cape Town), Prof. Francesco Petruccione (Stellenbosch University), and Prof. Ilya Sinayskiy (University of KwaZulu-Natal) exhibited good convergence and accuracy for small problems, but for large TSP problems both properties were very problematic. It was also prone to fluctuations during the optimization process, potentially limiting its utility in scenarios that require fast and reliable solutions. The **VQIA** algorithm was extremely slow to convergence, and took significantly longer than all other algorithms on all data sets. The **GD-QIA** algorithm had a very good convergence and accuracy for QUBO problems, but for TSP it had no convergence at all and its accuracy was anecdotal, suggesting that this algorithm was unsuitable for TSP.

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