Learning QAOA landscapes: Monte Carlo Tree Search with Iterative Search-space Restriction for Parameter Optimization

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Variational Quantum Algorithms (VQA) are the leading class of hybrid quantum-classical methods to cope with the limitations of near-term quantum hardware [1]. However, their effectiveness is hampered by the complexity of the classical parameter optimization, making the design of efficient optimization methods fundamental for leveraging the potential of VQAs. In this work, we propose a gradient-free parameter optimization strategy based on a modified version of the Monte-Carlo tree search (MCTS) algorithm [2] for the Quantum Approximate Optimization Algorithm (QAOA) [3], one of the most relevant algorithms in the VQA family. Our modifications allow MCTS to iteratively restrict the action space to exploit the parameter regularity inherent in optimal schedules and efficiently explore complex search domains [4]. The algorithm performs well in hard instances of 3-SAT and MaxCut problems, and exhibits remarkable robustness against noise. Our results shed light on the interplay of artificial intelligence and quantum information and provide a valuable step towards robust quantum computation with existing hardware.

Figures

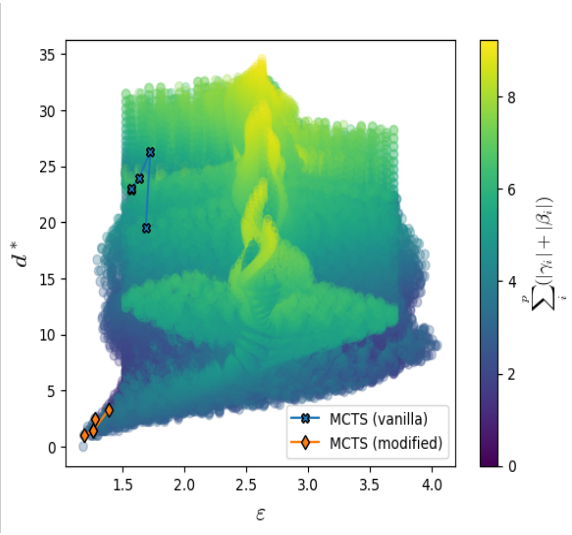

Figure 1: Distribution of leaf nodes in *P*=2 QAOA for a 3-SAT instance according to the distance from the optimal parameters and the final energy. Performance comparison of standard and modified MCTS.

References

[1] M. Cerezo *et al.*, Nat Rev Phys **3**, 625–644 (2021).
[2] M. Świechowski *et al.* Artif. Intell. Rev **56**, 2497–2562 (2023).
[3] E. Farhi, arXiv:1411.4028 (2014).
[4] A. Agirre, E. van Nieuwenburg, M. Wauters in preparation.