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A comparison of QAOA with Quantum and Simulated Annealing

We present a comparison between the Quantum Approximate Optimization Algorithm (QAOA) [1] with a competing quantum method, Quantum Annealing (QA), and a competing classical method, Simulated Annealing (SA). To achieve this, we reverse engineer QAOA to find problem instances defined with respect to their spectral properties which are exactly solvable with an one-block version of QAOA. Within this class, we find 4-local instances which are hard to solve with both QA and SA. Consequently, our results define a first demarcation line between QAOA, Simulated Annealing and Quantum Annealing. To examine the computational power of this class of exactly solvable problems of QAOA we demonstrate that the QAOA circuit does not build up any entanglement and that there exists a classically efficient algorithm that can solve these instances. Our findings highlight the fundamental differences between an interference-based search heuristic such as QAOA and heuristics that are based on thermal and quantum fluctuations like SA and QA respectively.

[1] Farhi, E., Goldstone, J., & Gutmann, S. (2014). A quantum approximate optimization algorithm. arXiv preprint arXiv:1411.4028.