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Complexity of the Quantum Adiabatic Algorithm

ITAY HEN, UC Santa Cruz and NASA Ames Research Center

The Quantum Adiabatic Algorithm (QAA) has been proposed as a mechanism for efficiently solving optimization problems on a quantum computer. Since adiabatic computation is analog in nature and does not require the design and use of quantum gates, it can be thought of as a simpler and perhaps more profound method for performing quantum computations that might also be easier to implement experimentally. While these features have generated substantial research in QAA, to date there is still a lack of solid evidence that the algorithm can outperform classical optimization algorihms. Here, we discuss several aspects of the quantum adiabatic algorithm: We analyze the efficiency of the algorithm on several "hard" (NP) computational problems. Studying the size dependence of the typical minimum energy gap of the Hamiltonians of these problems using quantum Monte Carlo methods, we find that while for most problems the minimum gap decreases exponentially with the size of the problem, indicating that the QAA is not more efficient than existing classical search algorithms, for other problems there is evidence to suggest that the gap may be polynomial near the phase transition. We also discuss applications of the QAA to "real life" problems and how they can be implemented on currently available (albeit prototypical) quantum hardware such as "D-Wave One", that impose serious restrictions as to which type of problems may be tested. Finally, we discuss different approaches to find improved implementations of the algorithm such as local adiabatic evolution, adaptive methods, local search in Hamiltonian space and others.