Quantum Annealing with Bias Fields

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Quantum annealing is a method to solve optimization problems via Hamiltonian engineering and quantum state preparation. The method requires that an energy gap protects the state of the system, as it evolves from the chosen initial state to the targeted ground state. Unfortunately, for initial states which are agnostic to the problem, this is typically not the case. However, even limited knowledge of the target state can be used to "smoothen" the evolution, and thereby, to greatly increase the efficiency of the annealing method. A concrete and simple strategy to achieve this is presented in this talk: An initial guess for the target state is incorporated in the annealing dynamics through bias fields which slightly rotate the spins/qubits towards the targeted state (see Fig. 1). If the initial guess is sufficiently close to the target state (specifically, with an error not larger than 40%), this procedure significantly increases the annealing fidelity (see Fig. 2). Iterative annealing runs can be used to generate and improve the initial guess.

We have tested this strategy via its simulation on a classical HPC cluster, and find that it significantly improves the annealing results for most instances of a NP-complete test problem. The proposed procedure can readily be implemented in present-day quantum annealers.

References

[1] Tobias Grass: Quantum annealing with longitudinal bias fields, Phys. Rev. Lett. 123 (2019) 120501

Figures

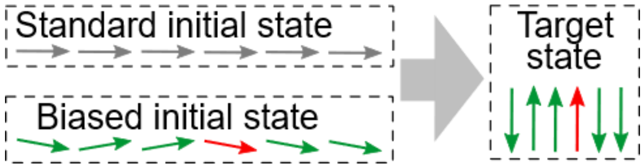

Figure 1: Standard vs. biased annealing. While standard annealing starts from a state which is agnostic to the target state, the biased annealing incorporates an (imperfect) guess of the target state into the initial state.

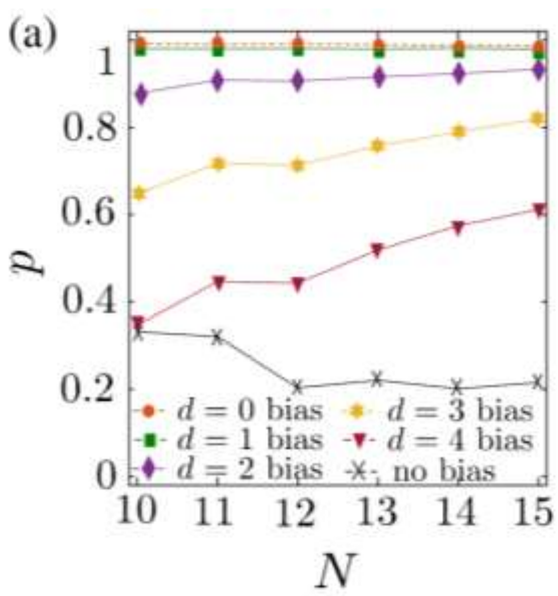

Figure 2: Annealing fidelity p for a problem with N spins/qubits when initialized in a biased state with d errors. If the initial guess contains less than 40% erroneous bits, the bias produces significant fidelity enhancement.