Quantum annealing: Optimization by quantum mechanics

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Quantum annealing is a generic algorithm to approximately solve optimization problems using quantum mechanical state transitions. It has been shown through a number of numerical studies that quantum annealing performs more efficiently than the conventional simulated annealing that uses classical thermal fluctuations to search the phase space for the optimal state. I first review the basic ideas of quantum annealing and present some of the numerical results to illustrate the relative performance of quantum annealing versus classical simulated annealing. Then I show our recent results on the convergence conditions of quantum annealing. These results provide a mathematical background for the reliability of quantum annealing, similarly to the theorem of Geman and Geman for the convergence condition of simulated annealing. In particular I will explain a remarkable fact that the same annealing schedule, i.e. the rate to decrease quantum fluctuations, applies to quite different types of dynamics of quantum Monte Carlo, Green's function Monte Carlo, and the real-time Schrödinger equation. The method is a theory of stochastic processes for Monte Carlo implementations and an application of the adiabatic theorem for the real-time Schrödinger equation.