Reconsideration of adiabatic theorem toward efficient quantum annealing

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1. Digest
Focusing only on the energy gap is not enough for speedup of the quantum annealing

2. Preceding researches
Adjust the evolution rate based on the energy gap
Avoid first-order phase transition to expand the energy gap

Most of the preceding studies focused only on the energy gap

3. Purpose of this study
■ Adiabatic Theorem
The condition to obtain the ground state definitely
\[
\left| \frac{1}{\epsilon(t) - \epsilon_0(t)} \int \langle j(t) | \frac{d\hat{H}(t)}{dt} | 0(t) \rangle \right| \ll 1
\]
Transition probability
We confirmed the contribution of eigenstate to the transition probability

4. Result 1/2
The relationship between energy gap and excitation

■ Problem setting
Partition of 10 numbers
7.1, 2.5, 8.6, 6.9, 0.2
3.5, 3.7, 9.8, 2.4, 4.1

■ Hamiltonian of QA
\[ H(t) = \frac{1}{T} \hat{H}_0 + \left( 1 - \frac{t}{T} \right) \hat{H}_0 \]
linearly decreased
T is set to 100
\[ \hat{H}_0 = \sum_{i=1}^{N} \sum_{j>i}^{N} 2n_1 \sigma_i^x \sigma_j^x + \sum_{j=1}^{N} \sum_{n=2}^{n_{max}} \sigma_i^n \]
\[ \hat{H}_t = -\sum_{i=1}^{N} \sigma_i^x \]
Excitation cannot be explained by focusing only on the energy gap

5. Result 2/2
Contribution of eigenstate to transition probability

■ Energy gap
Energy gap

■ Probability of ground state
Probability of ground state
Excitation is suppressed despite small gap
Excitation occurs despite large gap

Transition probability depends strongly on the eigenstates in numerator

6. Future plan
Explore how to estimate eigenstates in large-scaled problem and realize speedup based on eigenstates

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