Reconsideration of adiabatic theorem toward efficient quantum annealing

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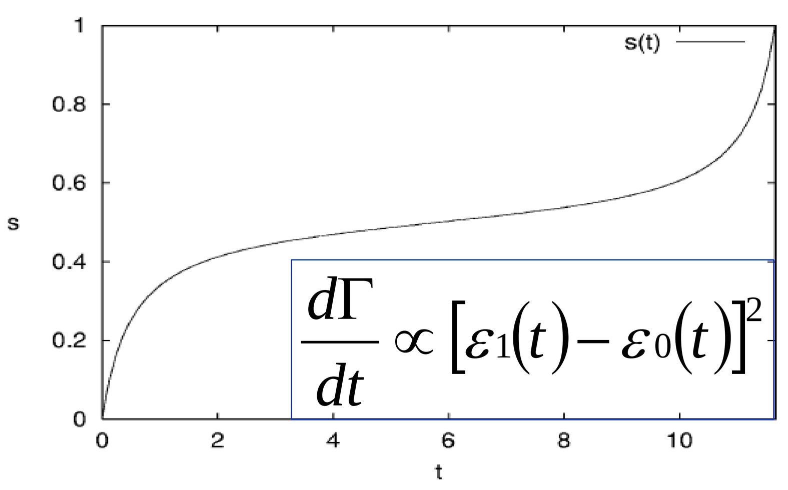
1. Digest

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

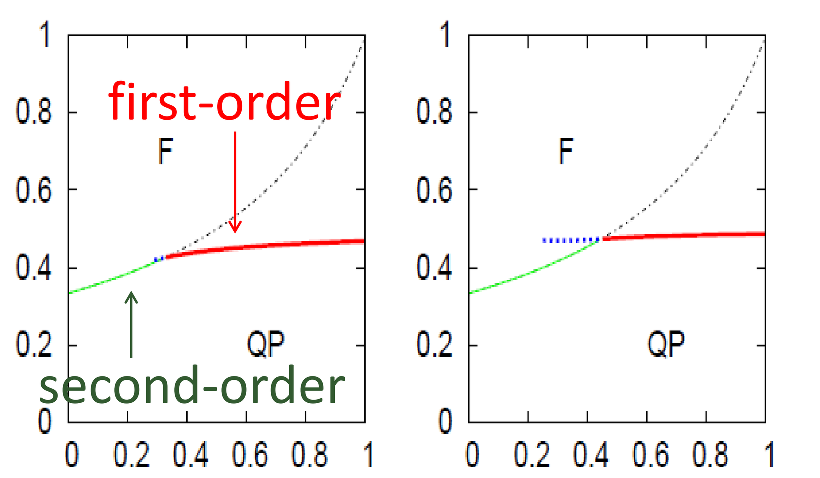
2. Preceding researches

Adjust the evolution rate
<u>based on the energy gap</u>



Roland et al., Phys. Rev. A, **65**, 042308 (2002)

Avoid first-order phase transition
<u>to expand the energy gap</u>



Seki et al., Phys. Rev. E, **85**, 051112 (2012)

Most of the preceding studies focused <u>only on the energy gap</u>

3. Purpose of this study

■ Adiabatic Theorem
The condition to obtain the ground state definitely

$$\left|\frac{1}{[\varepsilon_j(t)-\varepsilon_0(t)]^2}\langle j(t)|\frac{d\hat{H}(t)}{dt}|0(t)\rangle\right| << 1$$

Transition probability

We confirmed <u>the contribution of eigenstate</u> 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

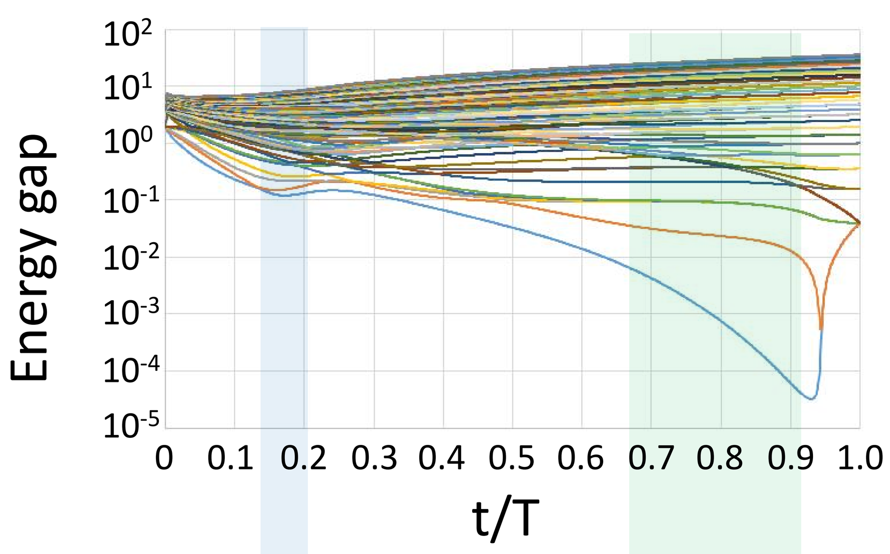
$$H(t)=\frac{t}{T}\hat{H}_0+\left(1-\frac{t}{T}\right)\hat{H}_q$$

linearly decreased
T is set to 100

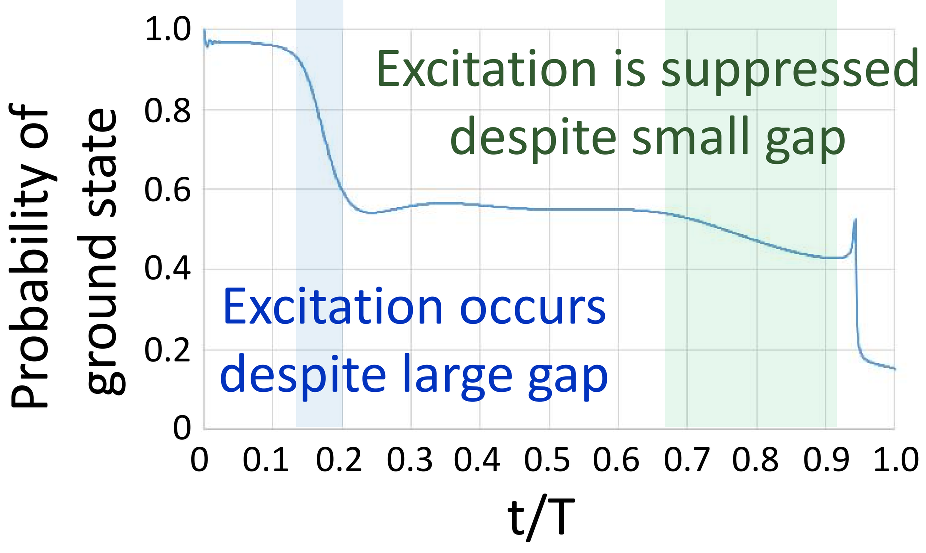
$$\hat{H}_0=\sum_{i=1}^{N}\sum_{j>i}^{N}2n_in_j\hat{\sigma}_i^z\hat{\sigma}_j^z+\sum_{i=1}^{N}2n_in_{10}\hat{\sigma}_i^z$$

$$\hat{H}_q=-\sum_{i=1}^{N}\hat{\sigma}_i^x$$

■ Energy gap



■ Probability of ground state



Excitation cannot be explained by focusing only on the energy gap

5. Result 2/2

Contribution of eigenstate to transition probability

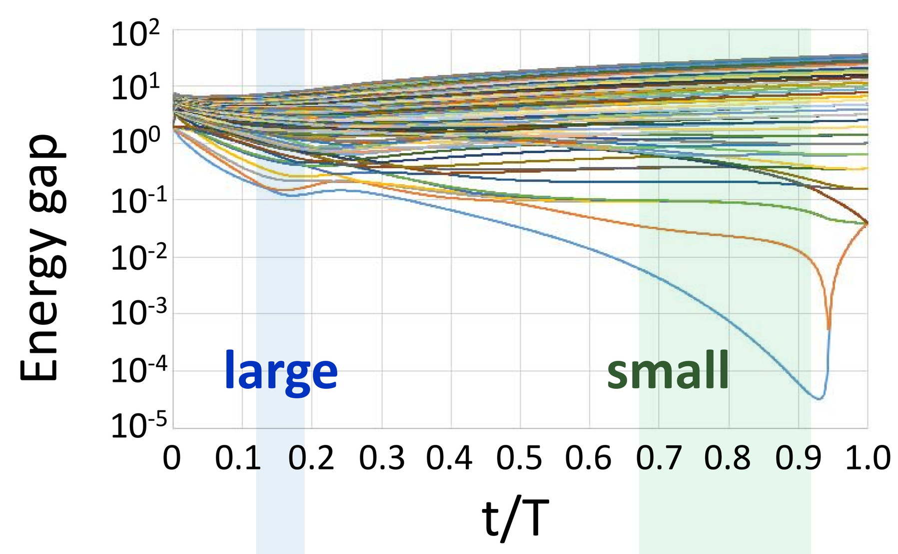
	blue region	green region
energy gap	large	small
transition probability	large	small

The above cannot be explained by only the energy gap

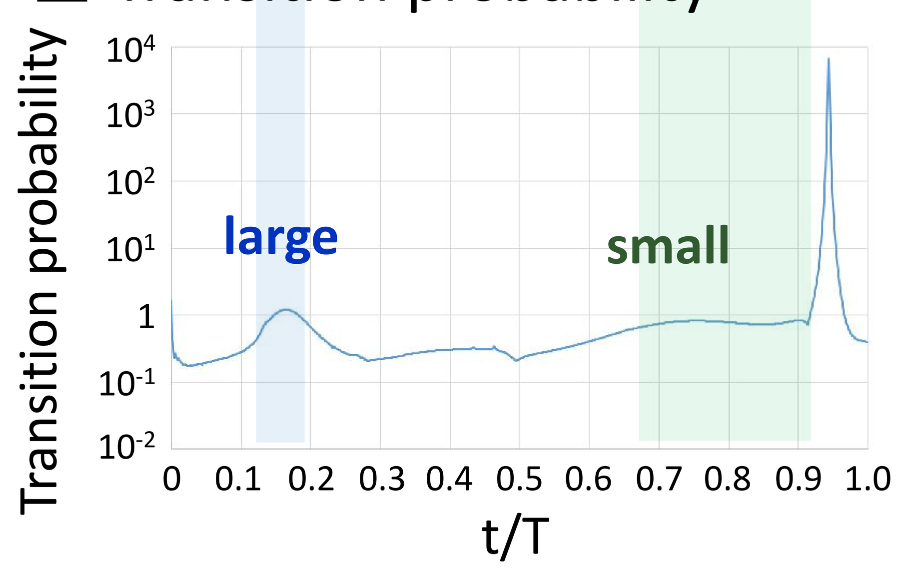
$$\sum_{j=1}^{2^N-1}\left|\frac{\langle j(t)|\frac{d\hat{H}(t)}{dt}|0(t)\rangle}{[\varepsilon_j(t)-\varepsilon_0(t)]^2}\right|$$

Sum over all the excited states

■ Energy gap



■ Transition probability



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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