IMPROVING QUANTUM ANNEALING BY ENGINEERING THE COUPLING TO THE ENVIRONMENT

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Abstract: A large class of optimisation problems can be mapped to the Ising model where all details are encoded in the coupling of spins. The task of the original mathematical optimisation is then equivalent to finding the ground state of the corresponding spin system which can be achieved via quantum annealing relying on the adiabatic theorem.

Key words: quantum system, optimisation problems, algorithms.

Introduction.

Quantum computation is expected to outstrip its classical counterpart in certain mathematical algorithms such as integer factorisation in data searches, and also in large scale optimisation, especially if the target function corresponds directly to the quantum-mechanical description of the system, ground state or correlation structure. Hence, should a challenging combinatorial problem be mapped onto a quantum system, a quantum simulator may indirectly solve the original problem in reasonable time.

Model.

Let us consider a collection of N identical, interacting qubits arranged at the vertices of an undirected graph, G, as depicted in Fig.1.:

$$H_G = -m_0\sigma_0^z - \frac{1}{2}\sum_{i,j=0}^{N} J_{ij}\sigma_i^z\sigma_j^z$$

With ferromagnetic coupling. A small field,

$$m_0 = 8 \times 10^{-2}\sigma_0$$

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$$H_{\text{ext}} = -me^{-t/\tau} \sum_{i=0}^{N} \sigma_i^x ,$$

where τ is the annealing time, and
$m = \mu B_0 B_0 \gg \max(J_{ij}) B_0 = 4$

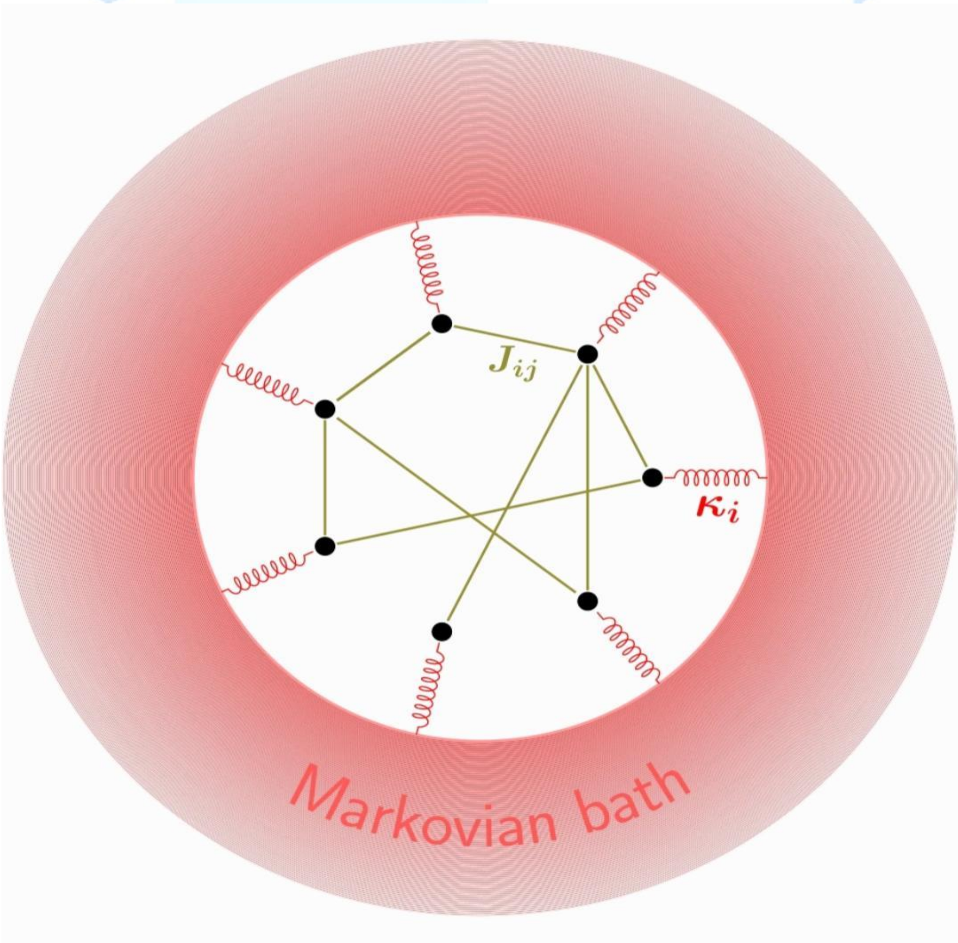

Figure 1.

Schematics of 7 qubits (black dots) interacting with each other with strengths Jij Ki.

The Ising system is brought into contact with an infinitely large bath in thermal equilibrium modelled as

$$H_{\text{bath}} = \sum_{\lambda} \hbar\omega_{\lambda} b_{\lambda}^{\dagger} b_{\lambda}.$$

The summation runs over the oscillator modes, while $b_{\lambda}^{\dagger} b_{\lambda}$

$$H_{\text{int}} = \sum_{i} A_i \otimes B,$$

where we opted for $A_i = \kappa_i(\sigma_i^{+} + \sigma_i^{-})\kappa_i$
$B = \sum_{\lambda}(b_{\lambda}^{\dagger} + b_{\lambda})\kappa_i$

We mention an alternative approach for regulate the system on a site-dependent basis, in which each qubit is controlled by its own transverse field, rather than an individually controlled interaction strength. Within a mean field like model Susa et al. showed that with such a spatio-temporal inhomogeneous control-field the detrimental first-order phase transition, present in a uniform system, can be avoided, hence the performance of the quantum annealing protocol can be improved.

List of used literature:

1. C.-H. Cheng, Y.-F. Huang, H.-C. Chen, T.-Y. Yao, Neural network-based estimation for OFDM channels. https://www.refseek.com/
2. E. Balevi, J.G. Andrews, Deep learning-based channel estimation for high-dimensional signals (2019). NPR