

Dynamical process on the bit-width-reduced Ising model and tuned method in simulated annealing

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This study is based on the results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

Outline

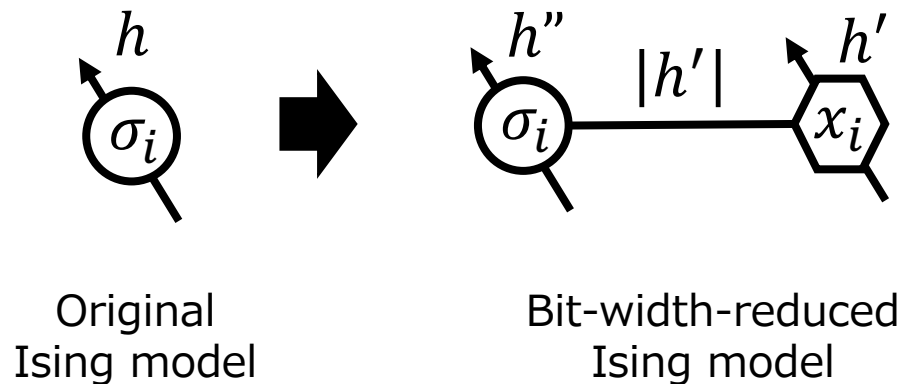
- Analysis of the dynamical process of original Ising model and bit-width-reduced Ising model of Simulated Annealing (SA).
- It is suggested that the dynamical process of the bit-width-reduced Ising model is different from that of the original Ising model, as shown by model analysis and experimental evaluations.

Introduction

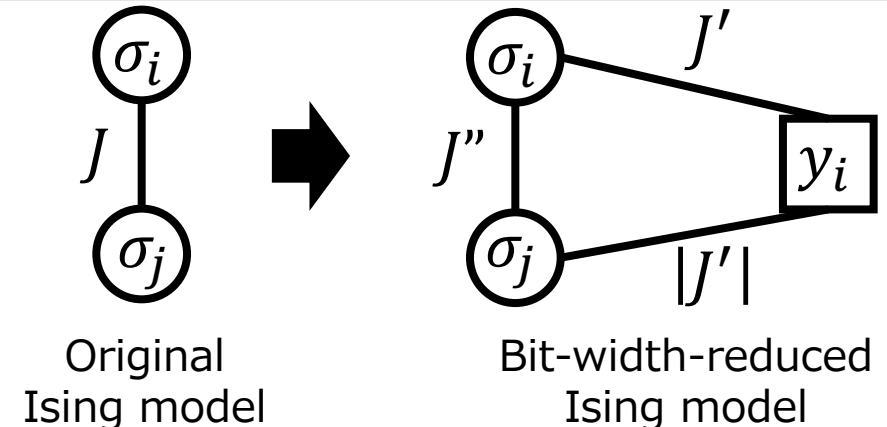
- The bit-width of the interaction and magnetic field coefficients in actual Ising machines is limited.
- Oku *et al.* proposed a new bit-width reduction method (Oku method) that can theoretically obtain the ground state of the original Ising model by adding auxiliary spins.

D. Oku, M. Tawada, S. Tanaka, and N. Togawa, *IEEE Trans. Comput.* (2020)

Magnetic fields

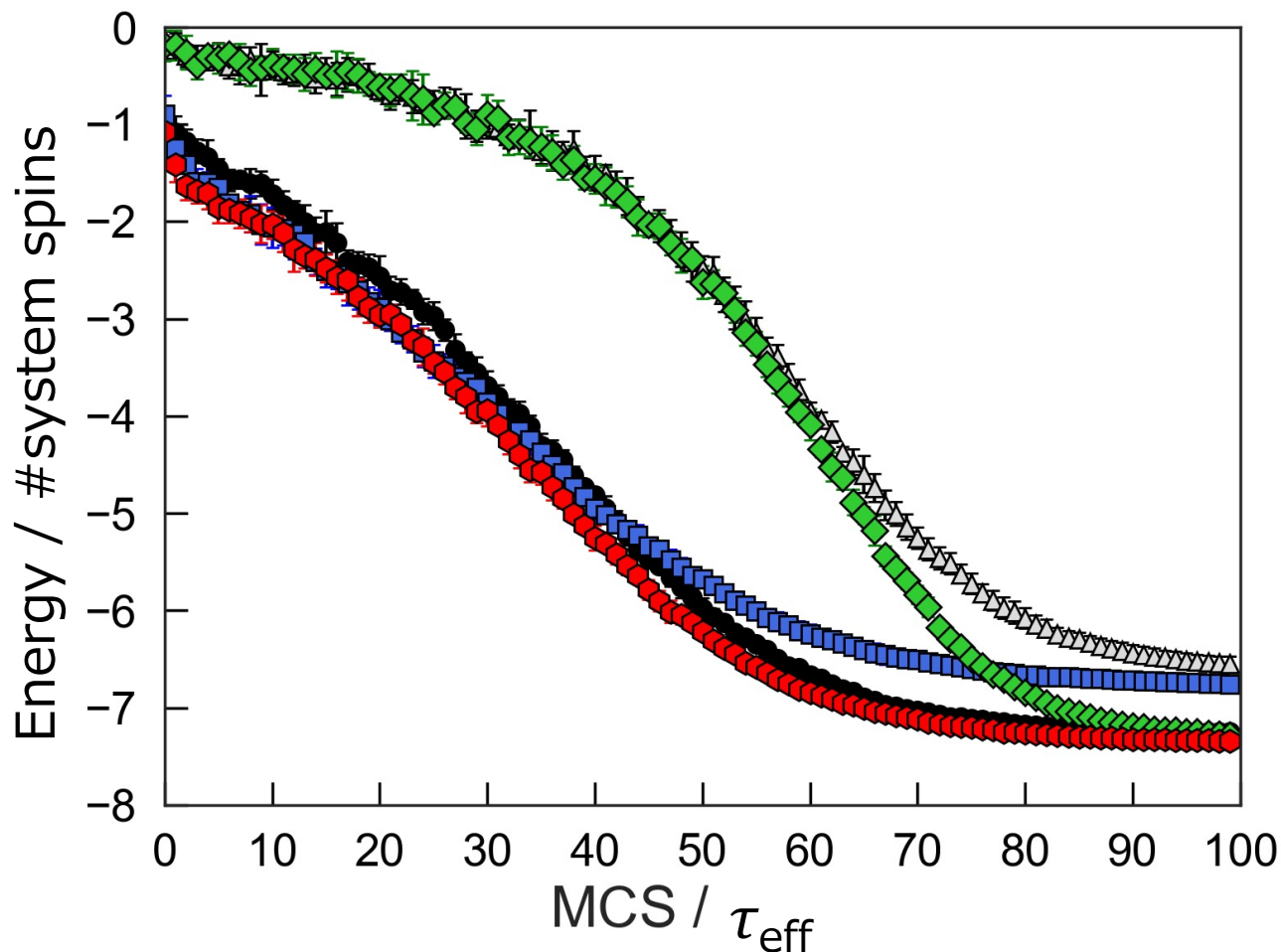


Interactions



- However, the dynamical process to the ground state in the bit-width-reduced Ising model is unknown.
- We analyzed the dynamical process of the bit-width-reduced Ising model using Oku method and studied the method to adjust conditions in simulated annealing.

Result



Color	Ising model	Temperature Schedule ¹	Inner loop ²
●	Original* (4-bits)	Original	Original
△		Original	Original
■	Bit-width-reduced (2-bits)	Proposed	Original
◆		Original	Proposed
⬡		Proposed	Proposed

1: S. Miyashita, S. Tanaka and M. Hirano, J. Phys. Soc. Jpn. 76 (2007) 083001

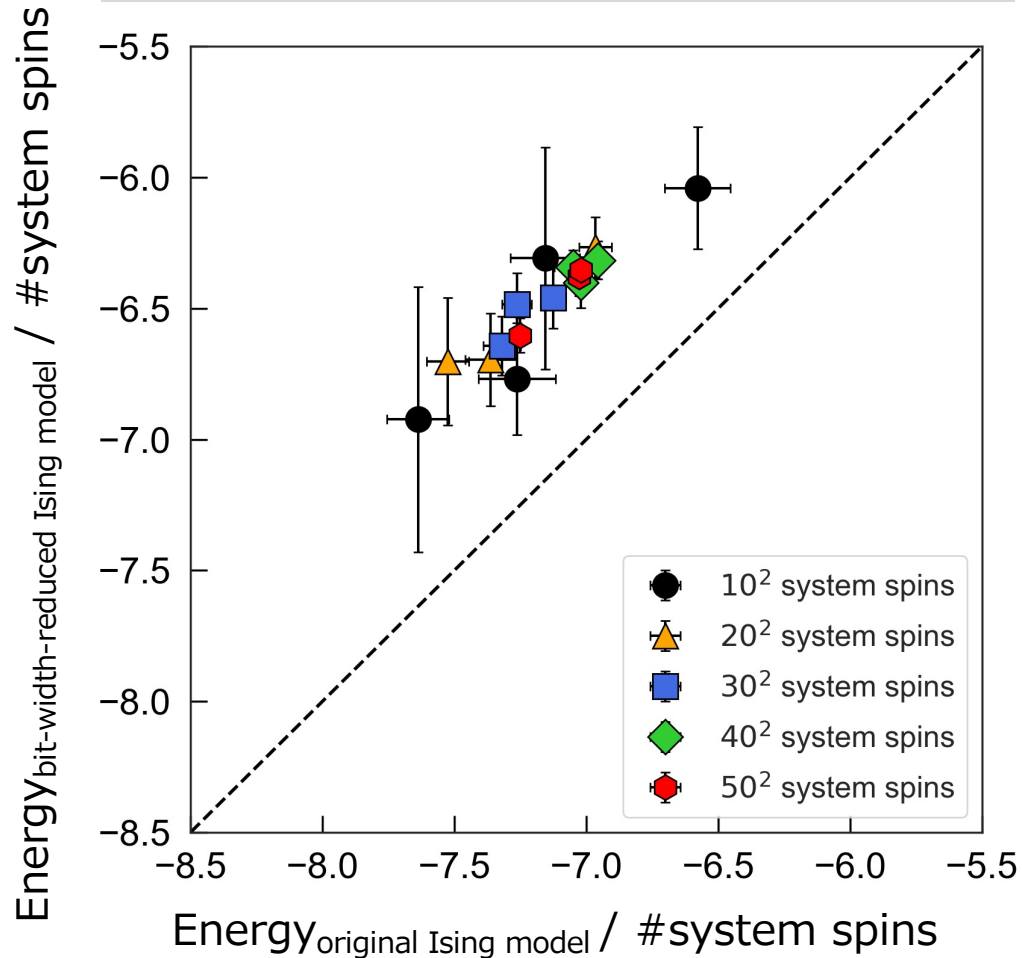
2: S. Tanaka and S. Miyashita, J. Phys. Soc. Jpn. 78 (2009) 084002

*: 50^2 square lattice, random interactions, random magnetic fields

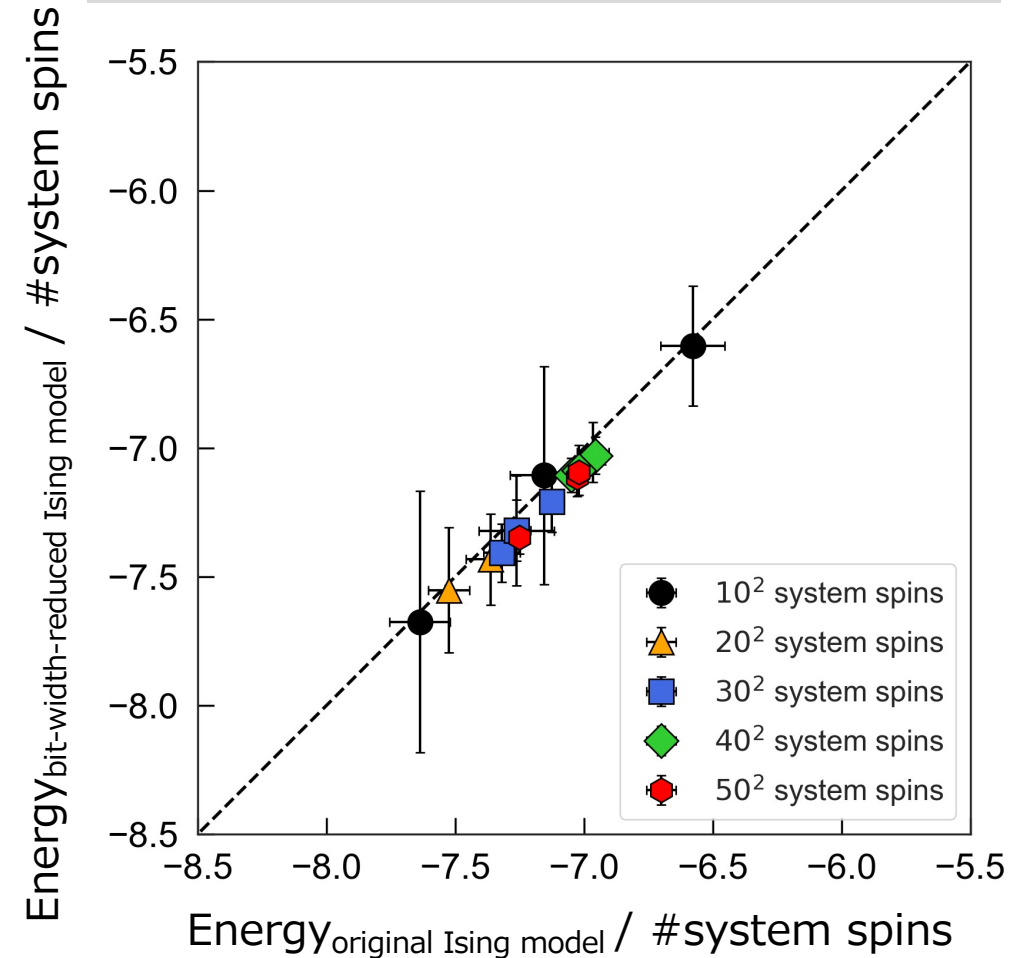
- The dynamical process of original Ising model and bit-width-reduced Ising model are different.
- Tuning the temperature schedule and inner loop reduced the difference of dynamical processes.

Result

Original SA parameters



Proposed SA parameters



- SA with the proposed parameters improves the solution accuracy of the bit-width-reduced Ising model.

Conclusion & Future Work

Conclusion

- SA results indicated that the dynamical processes of original Ising model and bit-width-reduced Ising model are different.
- The reasons for the different dynamical process are suggested to be (1) the effective temperature and (2) the entropy effect.
- The scheduling function of temperature is tuned based on (1) and (2), the difference in the dynamical process becomes smaller.
- SA using the proposed parameters improves the solution accuracy of the bit-width-reduced Ising model.

Future Work

- Analysis of the dynamical process to the ground state other than SA.
- Solve the bit-width-reduced Ising model using the proposed method on an implemented Ising machine.