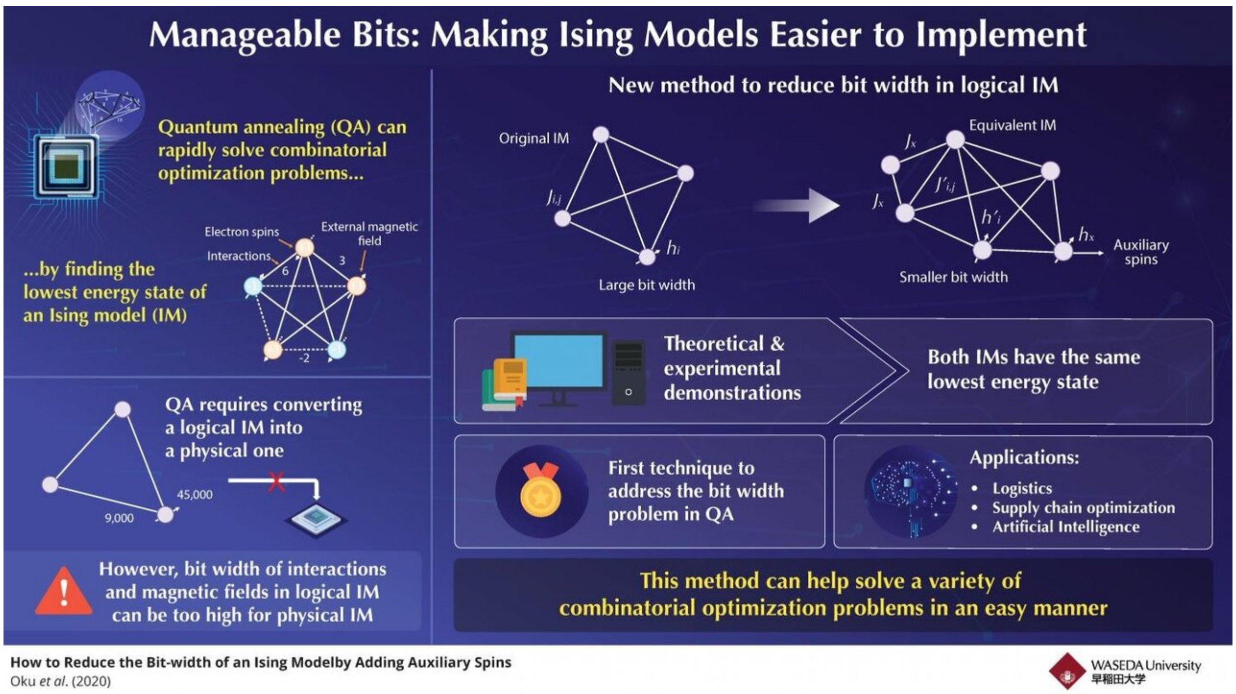
A bit too much: Reducing the bit width of Ising models for quantum annealing

January 6 2021



A method that can reduce the bit width of a quantum system called the Ising model to solve combinatorial optimization problems. Credit: Waseda University

Given a list of cities and the distances between each pair of cities, how do you determine the shortest route that visits each city exactly once and returns to the starting location? This famous problem is called the 'traveling salesman problem' and is an example of a combinatorial optimization problem. Solving these problems using conventional computers can be very time-consuming, and special devices called 'quantum annealers' have been created for this purpose.

Quantum annealers are designed to find the lowest energy state (or ground state) of what's known as an Ising model. Such models are abstract representations of a quantum mechanical system involving interacting spins that are also influenced by external magnetic fields. In the late 90s, scientists found that combinatorial optimization problems could be formulated as Ising models, which in turn could be physically implemented in quantum annealers. To obtain the solution to a combinatorial optimization problem, one simply has to observe the ground state reached in its associated quantum annealer after a short time.

One of the biggest challenges in this process is the transformation of the logical Ising model into a physically implementable Ising model suitable for quantum annealing. Sometimes, the numerical values of the spin interactions or the external magnetic fields require a number of bits to represent them (bit width) too large for a physical system. This severely limits the versatility and applicability of quantum annealers to real world problems. Fortunately, in a recent study published in *IEEE Transactions on Computers*, scientists from Japan have tackled this issue. Based purely on mathematical theory, they developed a method by which a given logical Ising model can be transformed into an equivalent model with a desired bit width so as to make it fit a desired physical implementation.

Their approach consists in adding auxiliary spins to the Ising model for problematic interactions or magnetic fields in such a way that the ground state (solution) of the transformed model is the same as that of the original model while also requiring a lower bit width. The technique is relatively simple and completely guaranteed to produce an equivalent Ising model with the same solution as the original. "Our strategy is the world's first to efficiently and theoretically address the bit-width reduction problem in the spin interactions and magnetic field coefficients in Ising models," remarks Professor Nozomu Togawa from Waseda University, Japan, who led the study.

The scientists also put their method to the test in several experiments, which further confirmed its validity. Prof. Togawa has high hopes, and he concludes by saying, "The approach developed in this study will widen the applicability of quantum annealers and make them much more attractive for people dealing with not only physical Ising models but all kinds of combinatorial optimization problems. Such problems are common in cryptography, logistics, and artificial intelligence, among many other fields."

More information: Daisuke Oku et al, How to Reduce the Bit-width of an Ising Model by Adding Auxiliary Spins, *IEEE Transactions on Computers* (2020). DOI: 10.1109/TC.2020.3045112

Provided by Waseda University