NEC Project

Title

Combinatorial optimization using quantum annealing ~Search for proper choices of solvers and evaluation of solutions on combinatorial optimization problems~

Sponsor NEC Corporation

NEC was founded in 1899 and is now focusing on developing solutions for the society that will help resolve many of the issues the world is facing and lead to the creation of a brighter and more prosperous society. Through co-creation initiatives with many different stakeholders, including customers and business partners, citizens and government agencies, and international institutions, we are actively devising new business models to create social value by harnessing our extensive ICT (Information and Communication Technology) assets.

Industry Mentors

TBA

Background

Artificial intelligence (AI) is increasingly being used to solve various real-world problems. One method for solving problems is selecting the best combination from an infinite number of choices generated through machine learning.

These kinds of complex combinational optimization problems take even supercomputers an enormous amount of time to solve, making it impossible to obtain accurate answers within the required time. Business, however, requires making the best decisions within at most a few tens of minutes.

As societies mature, their problems also increase in complexity, leading to an ever-increasing number of factors to consider in solving problems. In the future, the evolution of computer technologies capable of solving complex problems will lead to significant social changes across many fronts: time savings, energy and cost reduction, proper manpower allocation, labor shortage resolution, industrial optimization, and value creation.

Among quantum computers, quantum annealing machines, which use weights among qubits (Quantum bits) in performing computations, has received wide attention as a tool for solving complex combinational optimization problems within a short period of time. In 1999, NEC succeeded in demonstrating solid-state qubit operation in the quantum superposition state for the first time through a superconducting device. As it continued its research on ways to control the

superposition state, NEC at some point shifted to quantum annealing as the main focus for generating a suite of outcomes from its research efforts.

Project and Expectations

Recent advent of quantum annealers and digital annealers has brought a breakthrough in solving combinatorial optimization problems fast and accurately. However, size of target problems, for example, obstructs us in directly applying these solvers to the problems, and conventional approaches often outperform the new solvers.

Students are subjected to propose proper choices (or combinations) of the annealers and/or solvers, for Employee Shift Scheduling as an example, which give the most accurate solution in the shortest time. Students are also subjected to develop formulation of corresponding Ising models(*1) and estimate the applicability of each solver. NEC will provide datasets for these evaluations.

1) The quantum and classical annealers provided by D-wave systems Inc.(*2),
2) Solvers based on Xeon servers,
3) Solvers based on GPGPU servers,
4) Solvers based on NEC's Vector machine "SX-Aurora TSUBASA" servers(*3),

and their combinations are also available.

(*1)The Ising model, named after the physicist Ernst Ising, is a mathematical model of ferromagnetism in statistical mechanics. The model consists of discrete variables that represent magnetic dipole moments of atomic spins that can be in one of two states (+1 or −1). The spins are arranged in a graph, usually a lattice, allowing each spin to interact with its neighbors. Quantum annealers and digital annealers try to find the minimum energy state of this model, which corresponds to the optimal combination of the target problem.

(*2) Students can use the classical annealer provided by D-wave systems Inc. to solve the problems Then their Ising models will be executed by industrial mentors on the D-wave quantum annealer.

(*3) https://www.nec.com/en/global/solutions/hpc/

Requirements

Programming skills (Python, C, or MATLAB)

Recommended Readings and References

[1] Professor Hidethosh Nishimori's website on quantum annealing. http://www.stat.phys.titech.ac.jp/~nishimori/QA/q-annealing_e.html

[2] D-Wave's website. https://www.dwavesys.com/(*4)

[3] M. W. Johnson, et al., “Quantum annealing with manufactured spins," Nature **473**, 194 (2011).

[4] M. Aramon, et al., “Physics-Inspired Optimization for Quadratic Unconstrained Problems Using a Digital Annealer," arXiv:1806.08815.

(*4) You'll find materials on some applications of quantum annealing later on this website.