Tokyo Tech
Research Units

Quantum Computing Unit

Overview

After decades of continued efforts in basic research, a prototype quantum computer was announced and commercialized in 2011 under the protocol of quantum annealing proposed by the group led by Professor Hidetoshi Nishimori in 1998. The machine has since been upgraded to its current fourth generation, and has spurred a flurry of R&D activities in industry as well as in academia toward real-life applications. Quantum computers are expected to process some of the very complicated tasks that are out of reach of supercomputers. The list of such tasks considered within reach of near-future hardware includes traffic optimization, portfolio optimization, large-scale code debugging, solutions to fluid equations, air traffic control, and medical diagnosis. Research activities of the Unit will cover a broad range of areas of quantum annealing from basic theory to software and applications.

Research goals

Quantum annealing, a term taken from the metallurgy technique "annealing", is a metaheuristic (generic approximate algorithm) for optimization problems. Basic theories are still to be established on the mechanisms of enhancement of its performance. The Unit thus focuses on the following topics:

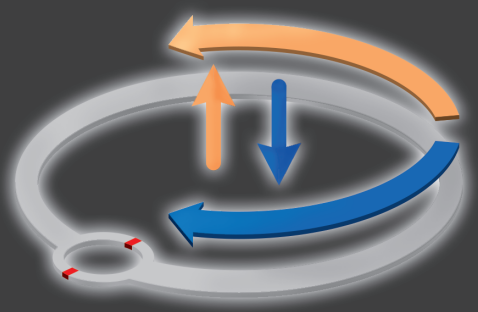
(1) Possible enhancement of the performance by the introduction of new mechanisms.
(2) Error correction in quantum annealing.
(3) General methodologies to express optimization problems with the Ising model.

Research Unit Leader **Hidetoshi Nishimori**

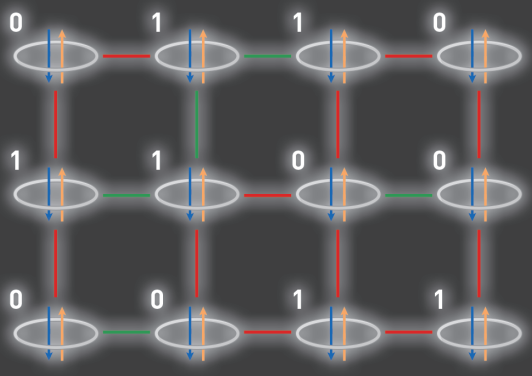
Profile

2018 Professor, Institute of Innovative Research, Tokyo Institute of Technology
2016 Dean, School of Science, Tokyo Institute of Technology
2011 Dean, Graduate School of Science, Tokyo Institute of Technology
1996 Professor, School of Science, Tokyo Institute of Technology
1990 Associate Professor, School of Science, Tokyo Institute of Technology
1984 Assistant Professor, School of Science, Tokyo Institute of Technology
1982 Doctor of Science, Department of Physics, School of Science, The University of Tokyo
1982 Research Associate, Department of Physics, Rutgers University
1981 Research Associate, Department of Physics, Carnegie-Mellon University
1977 Bachelor of Science, Department of Physics, Faculty of Science, The University of Tokyo

Quantum Bits and Annealing



In the quantum world, very small metal circuits at ultra-low temperature accommodate electric currents circling clockwise and anti-clockwise simultaneously, which are used to represent "0" and "1" simultaneously in a quantum bit (qubit). This is in marked contrast to the conventional computer, which uses bits that can only be set to a single state of "0" or "1".



As we turn on the interactions between qubits, the possibility of superposition of two states "0" and "1" is reduced at each qubit, and the system eventually settles to a single state.

Finding solutions to society's problems through quantum computing

Q Why was this research unit established?

With the rapid progress of quantum computing in recent years, establishing basic theories and systematic theoretical guidelines has become imperative. This Unit engages in comprehensive research, from basics to applications, in global and open environments, to support the adoption of quantum annealing in industry and society.

The traveling salesman problem (TSP)

As a prototypical example of combinatorial optimization problems, TSP seeks the shortest route a salesman can take to visit each city on a given map exactly once before returning to the origin. To apply quantum annealing to TSP, we express TSP in a quantum mechanical formula to find the solution using quantum-parallel processing.

Q What are the strengths of this research unit?

Unit Leader Nishimori established quantum annealing theory. He has been engaging in scientific exchanges with Google and NASA in quantum computing studies and participated in the establishment of standard IEEE quantum computing terminology. A world-class research team has been established for quantum annealing.

Q What is the path to achieving the unit's goals?

The goal of this Unit is to address speed, error correction, and other topics in quantum annealing. The Unit also entered into a partnership with the "Q+HPC data-driven research center for creation of science and technology" at Tohoku University through which they will promote research and development in a broad range of topics in basic research and applications. The Unit also aims to become a base for the formation of academia-industry consortiums, with the goal of applying quantum annealing to solve the problems faced by society.

Contact us

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Quantum Computing Unit

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