NEC Project:

Title Application of annealing machines to production planning optimization

Industrial Partner NEC Corporation

NEC (https://www.nec.com), founded in 1899, is now particularly addressing the development of solutions for society that will help resolve many issues the world is facing and which will engender the creation of a brighter and more prosperous society. Through co-creation initiatives with many different stakeholders, including customers, business partners, private individuals, government agencies, and international institutions, we are actively devising new business models to create social value by harnessing our extensive information and communication technology (ICT) assets.

Industrial Mentors

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Background

In recent years, the diversification of needs has changed the manufacturing scene from mass production to high-mix low volume production. On the other hand, there has been a remarkable development of general-purpose processing devices that can process multiple products with a single machine, such as 3D printers, laser cutting machines, computer numerical control machines, and surface mounting devices. As a result, factories are faced with the need to efficiently produce multiple types of products in a single day while sharing general-purpose processing devices. In order to achieve such production, efficient plans must be made regarding which products to produce, in what quantities, and in what order. However, production planning in such a situation is not easy, and that often remains dependent on certain skilled workers or inefficient methods. If an efficient production plan can be created in a stable manner, the competitiveness of the factories will be directly improved.

The production planning is also known as job-shop scheduling [1], which is a kind of combinatorial optimization problem. Combinatorial optimization problems are latent in social issues and are classified as NP-hard in terms of computational complexity theory.

Because of their difficulty, they are often left as an unsolvable part of a social problem. Optimization of production planning is a concrete example of such problems.

One approach to combinatorial optimization problems is simulated annealing [2]. While this generic method can be applied to many problems, it is not as efficient as the algorithms devised for each problem. However, optimization using annealing methods has recently been reevaluated. The quantum computer boom triggered that. Quantum computers are different from conventional computers in that they use quantum effects to perform calculations, and are expected to have the potential for high-speed calculations [3]. Quantum annealing [4,5], which incorporates quantum effects into simulated annealing, has been physically implemented and is provided by D-Wave Systems [6] as a quantum annealer. However, the scale of the problem this machine can handle is not large. The advent of the quantum annealer prompted vendors to develop pseudo-annealing environments that use supercomputers or other devices to perform annealing calculations. NEC provides Vector Annealing [7], an annealing-based algorithm implemented on NEC's own supercomputer, SX-Aurora TSUBASA [8]. These environments have the advantage of being able to handle large scale problems in a manner similar to quantum annealing. Thus, we can now utilize powerful optimization environments.

In the current situation, we can expect to solve complex production planning problems using the latest annealing machines. However, we have little knowledge of how big a problem can be solved and in what amount of time. In addition, there are various types of production planning problems, and we do not know what types of problems are easy or difficult to solve with annealing. Comparison with other methods is also an important issue.

Project and Expectations

In this project, we will approach the optimization problem of production planning mainly by annealing. We will study how to formulate problems and how to apply annealing to the problems effectively. As mentioned in Background, since there are various types of production plans, we will attempt to apply annealing to several types of problems. In addition, we will not only study the existing settings of the production plans but also create the settings themselves, to find out what settings annealing can be applied to. We expect to clarify how large a problem can be solved in a realistic amount

of time, and what kind of constraints can be handled. Performance comparison with methods other than annealing will be expected as an advanced task.

In this project, students will be able to use the latest annealing machines to solve real-world social problems. When using the annealing machine, coding in Python is required. Therefore, the students need to have Python programming skills. Knowledge of computer-based optimization methods is also desirable, while experience using annealing machines is not required. The environment for using the annealing machine will be prepared by NEC. At present, the use of D-Wave and Vector Annealing is envisioned. NEC will also provide materials for learning about production planning optimization and annealing. Examples of production planning will also be given. However, as mentioned above, the students are encouraged to create their own problems and study the applicability of annealing, not limited to those specific examples.

Requirements

Python programming skills.

References

[1] “The Job Shop Problem” in Google OR-Tools, https://developers.google.com/optimization/scheduling/job_shop

[2] S. Kirkpatrick, C. D. Gelatt Jr., M. P. Vecchi, “Optimization by Simulated Annealing,” Science **220**, 671 (1983); The article on simulated annealing in Wikipedia, https://en.wikipedia.org/wiki/Simulated_annealing

[3] “What is quantum computing?” in IBM’s website, https://www.ibm.com/topics/quantum-computing

[4] “What is Quantum Annealing?” in D-Wave System Documentation, https://docs.dwavesys.com/docs/latest/c_gs_2.html

[5] H. Nishimori, “Quantum Annealing,” http://www.qa.iir.titech.ac.jp/~nishimori/QA/q-annealing_e.html

[6] D-Wave Systems Inc., https://www.dwavesys.com/

[7] Announcement from NEC, “NEC launches simulated annealing service utilizing vector supercomputers,” https://www.nec.com/en/press/202109/global_20210901_01.html

[8] NEC’s website on SX-Aurora TSUBASA, https://www.hpc.nec/