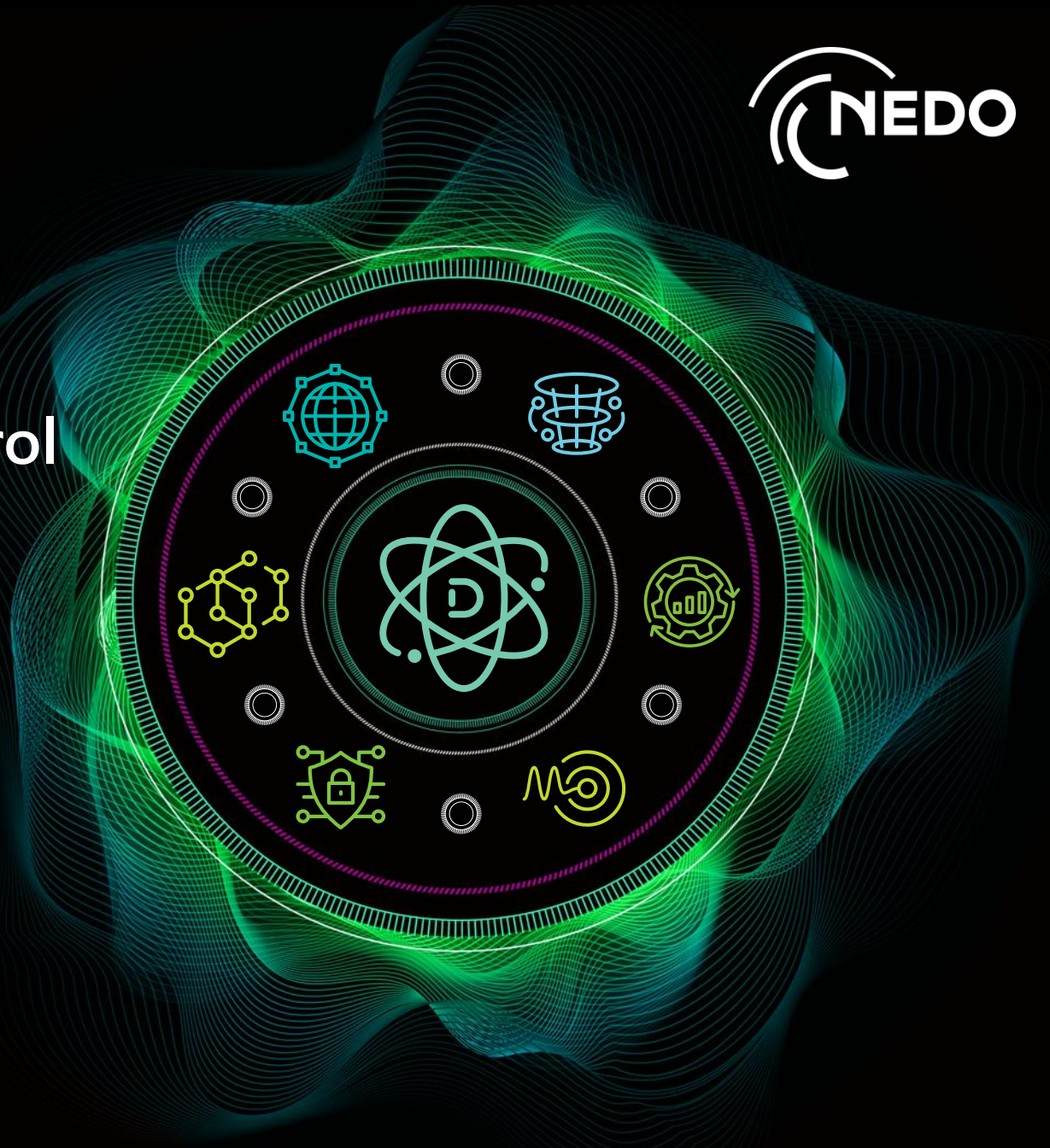
Quantum Computing Use Cases

Improvement of Robot Arm Control Using Quantum Reinforcement Learning

NTT DATA



New Energy and Industrial Technology Development Organization (NEDO)

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Validation

Industry	Other
Method	AI
Process	model learning
Category	Gate*

Background

- Reinforcement learning has emerged as an interesting method for controlling the movements of robotic arms, but **it is not ready for global application in learning diverse control functions due to two factors: the search strategy and the slow learning speed.**
- **More software-based control solutions with low-cost sensors have been pursued to achieve autonomous robot motion.**
- The hope is that **using learning-based techniques to control robots** will allow **robots to move into less structured environments, process unknown objects, and be better suited for multiple tasks** so that **instead of human pickers, they can select items of various sizes and shapes**.

Issues and motivation to be solved

- **Deep reinforcement learning (DRL) is attracting attention as a promising method** that combines deep learning (DL) and reinforcement learning * (RL). Since deep reinforcement learning is computationally intensive, **the computational resources and generalization capability of quantum computers are expected for practical application in the real world.**
  - ✓ **Generalization capability refers to the ability to leverage previous knowledge from the source environment to achieve good performance in the target environment and its applicability to flexible, long-term autonomy, and is considered to be a necessary step in creating artificial intelligence that behaves like humans**

Reinforcement learning *: A method that enables a computer agent to perform tasks through a dynamic environment and repeated trial and error interactions

Reference: NTT Data "Enhancement of Reinforcement Learning by Quantum Computation for Robot Arm Control" (https://www.nttdata.com/jp/ja/trends/data-insight/2023/031601/)
*Gate（gate-based）: A computing approach in which operations are applied sequentially to qubits to perform calculations. Similar in concept to logic circuits in classical computers, it can address a wide range of problems.

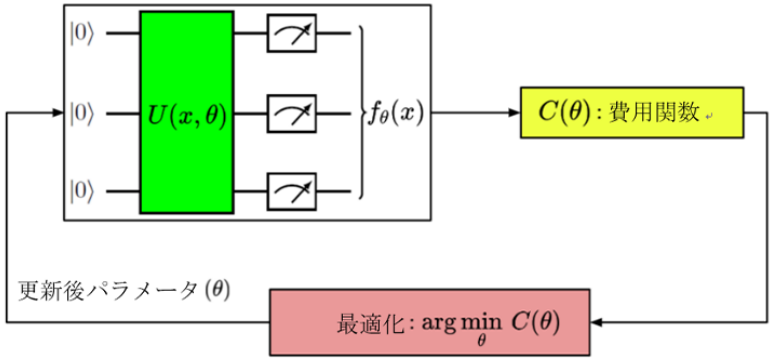
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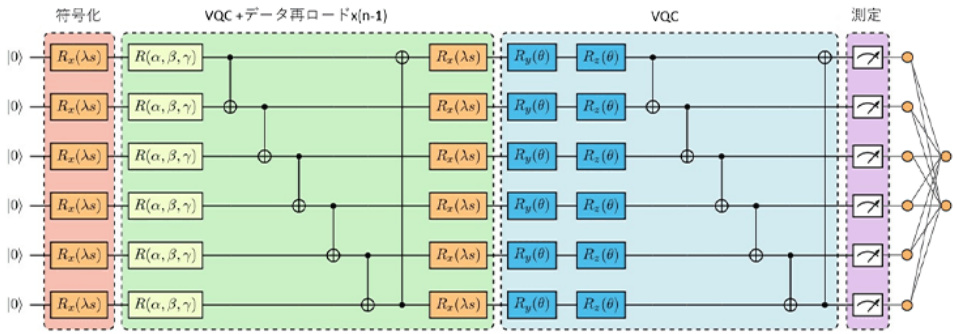
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Problem setting as a quantum computer

- **The use of quantum computers in improving robot arm control is variational quantum algorithms.**
  - ✓ A variational quantum algorithm is an algorithm that produces a quantum circuit that can perform a desired task by sequentially adjusting the configuration of the quantum circuit by a classical computer while monitoring the output of the quantum circuit as appropriate.
- In this research, **Variational quantum algorithm was applied to Soft Actor Critic (SAC), which is one of the state-of-the-art reinforcement learning methods for continuous control**.
- The verification is carried out using digital simulation of quantum circuits.



variational quantum algorithm



Actor Components Architecture
quantum-classical hybrid type of SAC

Reference: NTT Data, "Enhancement of Reinforcement Learning by Quantum Computation for Robot Arm Control " (https://www.nttdata.com/jp/ja/trends/data-insight/2023/031601/), IEICE," Variational Quantum Algorithms and Quantum Machine Learning " (https://app.journal.ieice.org/trial/104_11/k104_11_1166/index.html)
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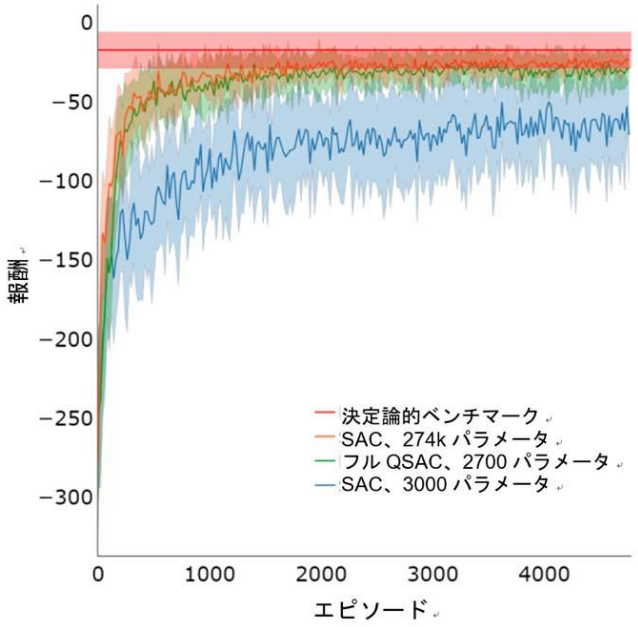
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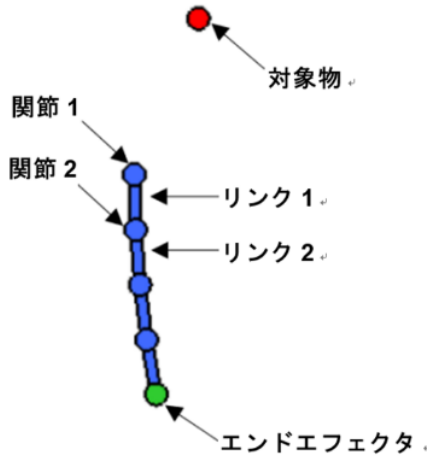
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Expected business benefits

- Through numerical simulations, **we show that actor-critic quantum strategies perform better than classical models of similar architectures, and there is a clear quantum advantage in the number of parameters that can be learned** on benchmark robot control tasks.
- However, the above is only verification in a test environment.



Learning curves of classical and quantum-classical SAC architectures tested in a robotic arm environment



Virtual two-dimensional four-joint robot arm tested in the study

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More use cases are available on our website. We invite you to explore them.
https://www.quantum-computing-use-cases.nedo.go.jp/english/

More Use Cases

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AI and Robotics Department (e-mail: quantum_ai@ml.nedo.go.jp)

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