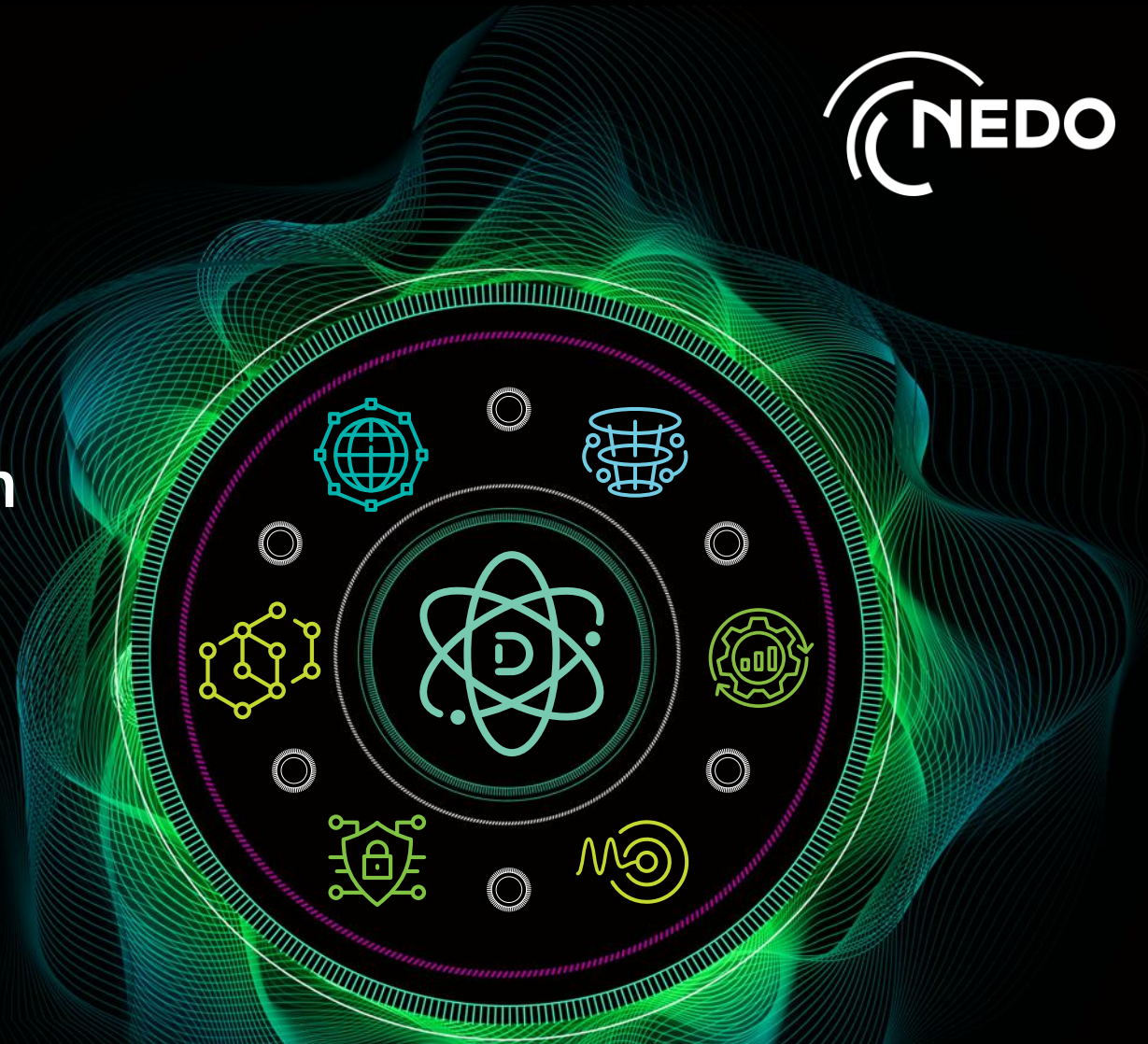
Quantum Computing Use Cases

Image Generation Using Quantum Neural Networks

Quemix



New Energy and Industrial Technology Development Organization (NEDO)

Quemix: Image Generation Using Quantum Neural Networks [2023/11] 1/3

Validation

Industry	Other
Method	AI
Process	inference
Category	Gate*

Background

- Generative AI that learns and provides the best/new answers The need for AI is expanding, and image generation that generates high-dimensional data is also realized.
- **Due to the need for large-scale operations such as image generation using generative AI, demand for computing resources and energy will increase, and there is concern about an increase in CO2 emissions.**
  - ✓ **Of the CO2 emitted by AI models, the majority** is *1, which is generated when **users use AI,** not when training AI models.
  - ✓ Image AI requires far more energy than text generation, and **using diffusion models to generate 1000 images would emit as much CO2 as driving an average gas-powered car for about 6.6 kilometers,** says Stable Diffusion.

Issues and motivation to be solved

- The diffusion model using the classical neural network model is widely used in image and video generation.
  - ✓ **In the diffusion model, noise is removed from original image data (pixel value) including random noise and converted into a desired image.**
- **However, quadratic scaling of the image data** (e.g., an 8 pixel image requires 64 elements) makes **high resolution images such as 4K images require simultaneous processing of large amounts of data, which is difficult for classical computers** and even worse for video generation
- Thus, the quantum algorithm vendor, **Quemix, replacing classical neural networks with quantum neural networks, aims at the possibility of large-scale image and video generation taking advantage of the advantages of simultaneous parallel computing of quantum computers.**

*1: MIT Technology Review"AI image generation consumes as much energy as a fully charged phone" (https://www.technologyreview.jp/s/323271/making-an-image-with-generative-ai-uses-as-much-energy-as-charging-your-phone/)
Quemix "Diffusion model based on quantum neural network with channel attention" (https://www.quemix.com/notes011)
*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.

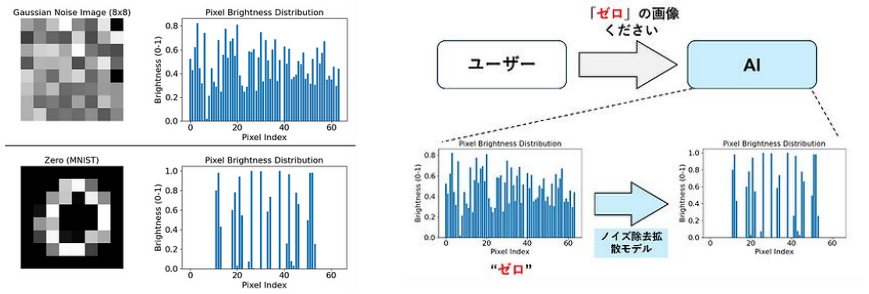
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Validation

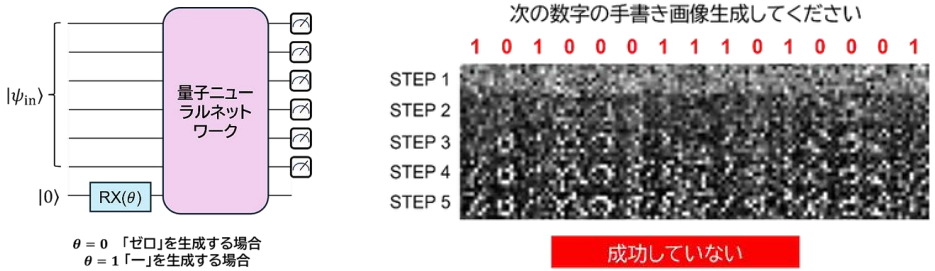
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Problem setting as a quantum computer

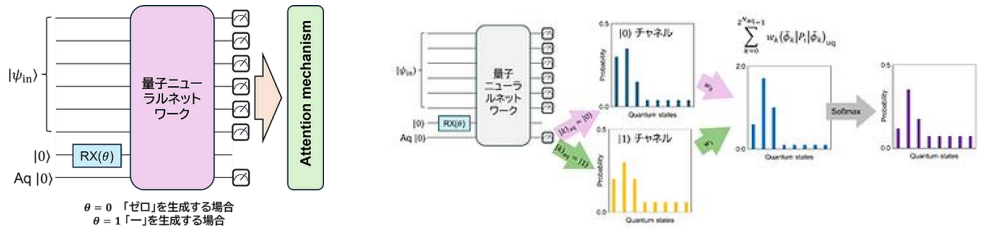
- Diffusion Model Using Classical Neural Network
  - ✓ Images are represented as two-dimensional matrices, with matrix elements corresponding to pixels.
  - ✓ When the AI is asked for a handwritten “zero, ” it generates an image by **converting the pixel values of a matrix representation random noise image into a handwritten“ zero.**
- Diffusion model using quantum neural network
  - ✓ **The 8 million elements needed to generate a 4 K image** would be difficult to process simultaneously with a classical neural network, **but a quantum computer could be used to process them at 23 bit speeds.**
  - ✓ Image generation, on the other hand, requires denoising
- **Diffusion Model Using Quantum Neural Network with Denoising Performance**
  - ✓ Denoising is a non-unitary operation that cannot be handled by the unitary operations allowed by quantum computers
  - ✓ Thus, large-scale operations are performed on quantum computers, and **we introduce a channel attention function that performs nonunitary operations to remove noise on classical computers.**



Generating Handwritten “0 ” by Diffusion Model in Classical NN Can Generate Denoised Output



Quantum circuit generating handwritten "0" or "1" via quantum neural network diffusion model and corresponding output (image generation fails due to noise)



Introducing denoising function (channel attention) to diffusion model of quantum NN

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Expected business benefits

- **QCNN performed better, outperforming the traditional approach of using a feedforward neural network as an additional post-processing**
- **Image generation by a classical computer is difficult with high-resolution images of 4K resolution or higher.** At 4 K resolution and above, vectors of about 8 million elements in length must be processed simultaneously during the denoising and spreading process. This challenge is **exacerbated by the 60~120 images per second video required for modern video production**.
  - ✓ A quantum computer could process the 8 million elements needed to produce a 4 K image in as little as 23 qubits.

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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

New Energy and Industrial Technology Development Organization (NEDO)
AI and Robotics Department (e-mail: quantum_ai@ml.nedo.go.jp)

This collection of use cases was obtained as a result of the work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) "Cyber-Physical Development Business of Quantum/Classical Hybrid Technology/Study of Use Case of Quantum Technology" and the "Post-5G Information and Communications System Infrastructure Reinforcement R & D Project (Quantum Industrialization)/Comprehensive Study for Promoting the Industrialization of Quantum Computers".