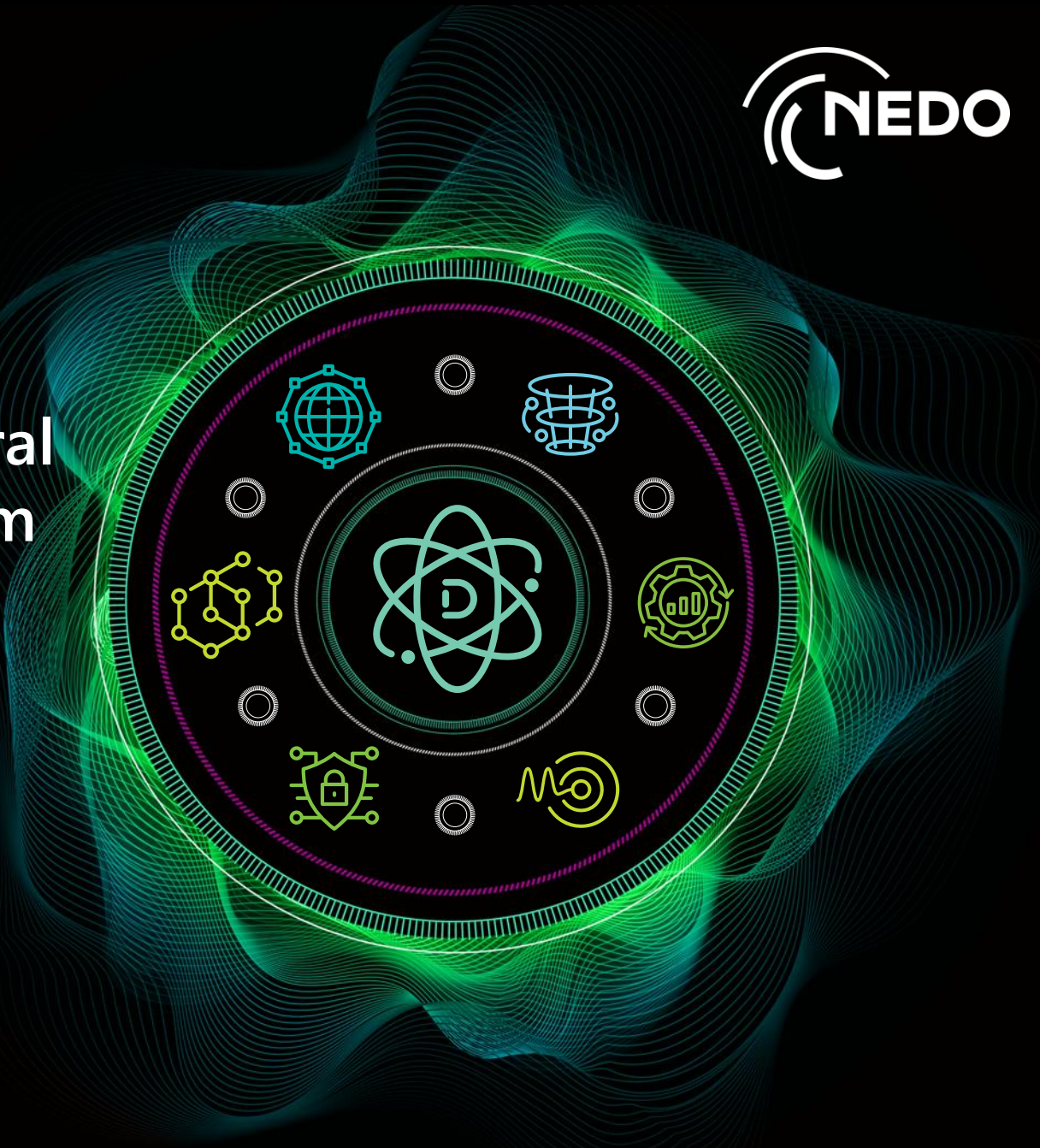
Quantum Computing Use Cases

Prevention of Resonance by Natural Frequency Analysis Using Quantum Phase Estimation

QunaSys



New Energy and Industrial Technology Development Organization (NEDO)

QunaSys: Prevention of Resonance by Natural Frequency Analysis Using Quantum Phase Estimation [2023/07] 1/2

Validation

Industry	Other
Method	Simulation
App Classification	CAE (Stress Analysis)
Category	Gate*

Background

- QunaSys is **Examining the Applications of Quantum Computers in the CAE Field** and discusses the potential applications of quantum computers, their impact, and comparisons with classical computation, mainly from a technical perspective, in two phases of the quantum computer paradigm: the NISQ era and the FTQC era. A CAE study group was held in which JX Oil Exploration Co., Ltd. and Murata Manufacturing Co., Ltd. participated to **gather suggestions on the direction of utilization based on the characteristics of quantum computers.**
- **The quantum phase estimation algorithm * has become a source of exponential quantum acceleration in many applications including quantum chemistry.**
- Natural frequency analysis of structures is **of industrial importance to prevent damage and noise from resonance.**
  - ✓ Natural frequency analysis is an analysis that generates resonance when the frequency of the input load coincides with the natural frequency of the structure side, preventing unpleasant vibration, noise, and damage.

Issues and motivation to be solved

- Since quantum phase estimation can solve eigenvalue problems, it has applications in quantum chemistry, or **if we can find other eigenvalue problems that quantum computers can solve exponentially faster, it will open up a promising use case.**
- In this project, **application to natural frequency analysis** is being considered as a new target.

Quantum phase estimation algorithm *: A method for estimating the eigenvalue associated with a given eigenvector of a unitary operation

Reference: QunaSys "Natural frequency analysis by quantum computer using quantum phase estimation algorithm" (https://unit.aist.go.jp/g-quat/ja/events/img/CAE_20240509-10/20240510_10_Kanno.pdf)
*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.

QunaSys: Prevention of Resonance by Natural Frequency Analysis Using Quantum Phase Estimation [2023/07] 2/2

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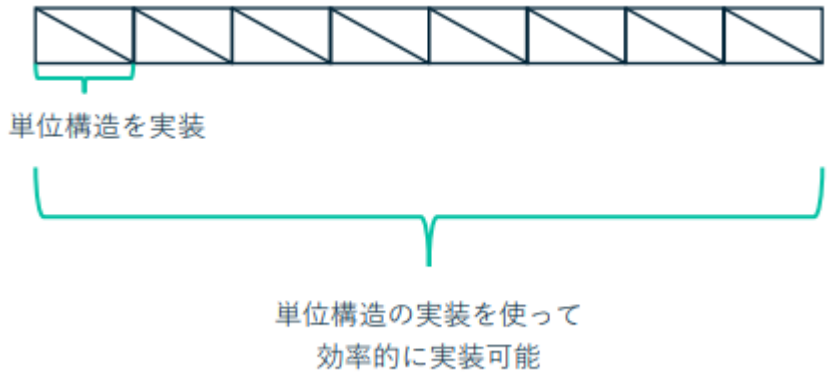
Problem setting as a quantum computer

- The purpose of this project is to **propose natural frequency analysis** as a new application of the quantum phase estimation algorithm.
- Calculated LV1 (constant spring constant) and LV2 (two types of spring constant) for N spring-connected mass points connected in one dimension
  - ✓ After preparing the input by performing coarse calculation on a classical computer, we implemented quantum phase estimation at the gate level for a one-dimensional system.
  - ✓ An efficient implementation for repetitive systems is also proposed.
- The HW used is not specified, but since QunaSys is working on a gate-based quantum computer, it is assumed to be a gate-based quantum computer.

Expected business benefits

- Calculations were performed for LV1 (constant spring constant) and LV2 (two types of spring constant) for N spring-connected mass points connected in one dimension.
- For a one-dimensional system, we implemented quantum phase estimation at the gate level and **showed exponential acceleration throughout the calculation.**
  - ✓ Qubitization * was utilized for the natural frequency analysis, and the gate number was O (log N) for N mass points (O (N) for a classical computer) in the whole quantum circuit.

Qubitization *: A method to convert Hamiltonian into a form that can estimate quantum phase using fewer resources than previous methods



Systems where this approach can be applied repeatedly

2^n	code distance	# of physical qubits	runtime
2^{32}	25	$\sim 5.2 \times 10^5$	~ 23 min.
2^{64}	25	$\sim 8.5 \times 10^5$	~ 45 min.
2^{128}	27	$\sim 17.5 \times 10^5$	~ 90 min.

n number and estimated computation time in LV2



due to strong wind resonance
Collapsed Tacoma Bridge (1940)

Natural frequency analysis by quantum computer using quantum phase estimation algorithm (https://unit.aist.go.jp/g-quat/ja/events/img/CAE_20240509-10/20240510_10_Kanno.pdf), qmedia"What are the strengths of "lab-initiated ventures"? Two companies working on quantum computers and quantum annealing look ahead to social implementation" (https://www.qmedia.jp/qunasys-jij-interview/)
*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.

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".