Quantum Error Mitigation via Quantum-Noise-Effect Circuit Groups

Research and development of quantum computers (calculators), from hardware to software, has shown steady progress in recent years, spanning academia and industry. Quantum computers are expected to be useful in solving certain natural and social science problems, such as materials development, quantum chemistry, and optimization problems. On the other hand, qubits are vulnerable to (quantum) noise. Therefore, the key to effective use of quantum computers is how to reduce the effects of quantum noise and produce reliable computational results.

In this R&D, we constructed a quantum error reduction method using a group of noise effect quantum circuits, a group of quantum circuits that represent quantum noise effects, the source of quantum computation errors, as shown in Figure 1. The effectiveness of this method was verified by quantum simulations for various algorithms. Since this method consists of gate operations and quantum measurements, it can be applied to any quantum hardware, quantum algorithms, and a wide variety of quantum noises. Furthermore, it can be performed as a software operation [1].
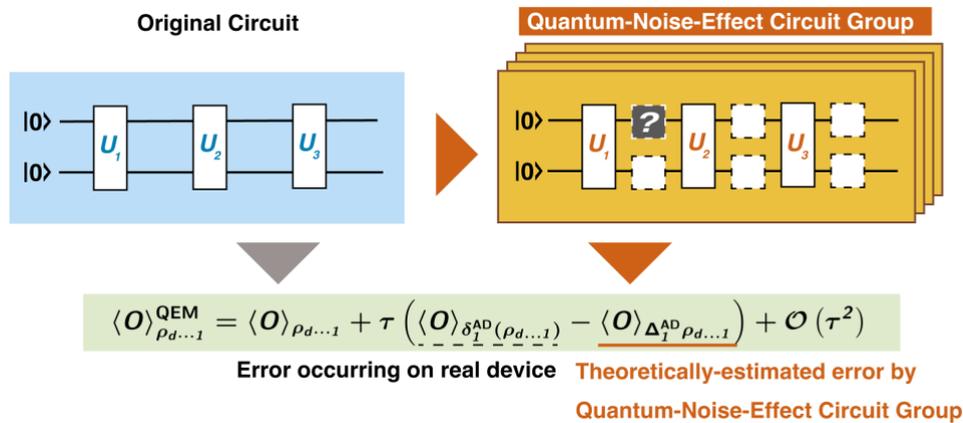

Original Circuit

$|0\rangle$ — U_1 — U_2 — U_3
$|0\rangle$

Quantum-Noise-Effect Circuit Group

$|0\rangle$ — U_1 — ? — U_2 — U_3
$|0\rangle$

$$\langle O \rangle^{\text{QEM}}_{\rho_{d\cdots1}} = \langle O \rangle_{\rho_{d\cdots1}} + \tau \left(\langle O \rangle_{\delta_1^{\text{AD}}(\rho_{d\cdots1})} - \langle O \rangle_{\Delta_1^{\text{AD}}\rho_{d\cdots1}} \right) + \mathcal{O}\left(\tau^2\right)$$

Error occurring on real device   **Theoretically-estimated error by Quantum-Noise-Effect Circuit Group**

Figure 1.   Noise Effect Quantum

Reference：

[1] Yusuke Hama and Hirofumi Nishi, arXiv:2205.13907.