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Noise mitigation of Quantum Circuits using Fictitious Copies

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Quantum computers promise better scaling for problems that are intractable on classical computers, however current devices are limited by noise, which only permits shallow depth circuits and restricts the potential algorithms that can be run. Nonetheless, many error mitigation schemes have been developed which use extra quantum or classical resources to recover corrected observables from noisy hardware. One such technique is virtual distillation (VD), which uses multiple copies of the circuit with entangled projections to give noise-free expectation values. However, direct implementation of VD requires prohibitively deep, noisy entangling circuits[1] or a large number of shallow circuits[2]. Here, we present a novel error mitigation technique inspired by VD that generates fictitious, non-entangled copies and corrects expectation values in postprocessing based on their joint probability distribution. Rather than relying on additional qubits and circuit depth, our method only requires increased sampling with the desired amount of error mitigation. We find our technique, optimally, is equivalent to virtual distillation but has state dependent performance. We therefore combine our technique with the quantum computed moments (QCM) method[3], which allows us to prepare the approximate ground states that are better corrected with our technique and still recover the ground state energy. We demonstrate our technique can find the exact ground state energy of molecular and spin models under simulated noise models as well as real experiments on IBM superconducting devices.

[1] Phys. Rev. X 11, 041036 (2021)

[2] Phys. Rev. Research 6, 033223 (2024)

[3] Quantum 4, 373 (2020)

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