Efficient Quantum Expectations Estimation via Hybrid Pauli Decomposition

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Abstract

We present a novel quantum-classical hybrid method for estimating expectation values of n-qubit matrices $M \in C^{2n2n}$. Our approach, termed hybrid Pauli decomposition, significantly reduces quantum circuit requirements compared to standard techniques. While conventional methods need 4n distinct circuits, our algorithm uses at most 2n, with further reductions for banded matrices. The key innovation lies in constructing observables as Kronecker products of singlequbit Pauli operators and computational basis projections. This allows simultaneous estimation of 2n matrix entries through classical post-processing of quantum measurements. By minimizing quantum resources, our method is particularly suited for noisy intermediatescale quantum (NISQ) devices. It has the potential to enhance various quantum algorithms relying on expectation estimation, including variational quantum eigensolvers and quantum approximate optimization algorithms, thereby expanding the practical applications of near-term quantum computers.

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