Simulating time-dependent expectation values by Clifford perturbation theory and sparse Pauli dynamics

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Here, we present new approaches to simulating quantum circuit expectation values quantum dynamics based on Clifford perturbation theory [1] and sparse Pauli dynamics [2, 3], two methods that propagate the quantum-mechanical observable in the Heisenberg picture. Both methods leverage the fact that performing Clifford unitary evolution can be performed efficiently in time that scales polynomially with the system size. The benefits of using sparse Pauli dynamics are illustrated by the classical simulation of a recent IBM's quantum simulation experiment, where it was implied that the 127-qubit Eagle quantum processor augmented with an error mitigation scheme can perform simulations of quantum dynamics that go beyond the capabilities of classical computers. There, sparse Pauli dynamics is capable of reproducing exact results with a comparable accuracy and much lower computational cost compared to the quantum simulation. Furthermore, it outperforms other, more conventional classical simulation techniques, such as those based on the matrix-product states and operators. Finally, we apply sparse Pauli dynamics to simulate transport properties, e.g., spin and energy diffusion constants, of spin lattice systems in the high-temperature regime.

[1] T. Begušić, K. Hejazi, and G. K. Chan, Simulating quantum circuit expectation values by Clifford perturbation theory, arXiv:2306.04797 [quant-ph] (2023).

[2] T. Begušić and G. K. Chan, Fast classical simulation of evidence for the utility of quantum computing before fault tolerance, arXiv:2306.16372 [quant-ph] (2023).

[3] T. Begušić, J. Gray, and G. K. Chan, Fast and converged classical simulations of evidence for the utility of quantum computing before fault tolerance, Sci. Adv. (in press, arXiv:2308.05077 [quant-ph]) (2023).