Distributed Quantum Dynamics on near-term quantum processors

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Simulations of quantum dynamics are a key application of near-term quantum computing [1], but are hindered by the twin challenges of noise and small device scale, which limit the executable circuit depths and the number of qubits the algorithm can be run on.
Towards overcoming these obstacles we develop and implement a distributed variant of the projected Variational Quantum Dynamics [2] which we dub dp-VQD (Fig. 1), which allows to simultaneously alleviate circuit depth and width limitations. We employ the wire-cutting technique [3], which can be executed on the existing devices without quantum or classical communication.
We demonstrate the full variational training on noisy simulators, and execute and perform the reconstruction on real IBM quantum devices for the Heisenberg and Hubbard model dynamics.
The algorithm allows to execute Hamiltonian evolution simulations for problem sizes exceeding devices' nominal qubit counts, and the combination of multiple small devices in a distributed computation.

References

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[3] M. Caleffi, M. Amoretti, D. Ferrari, J. Illiano, A. Manzalini, and A. S. Cacciapuot, Computer Networks **254**, 110672 (2024)

Figures

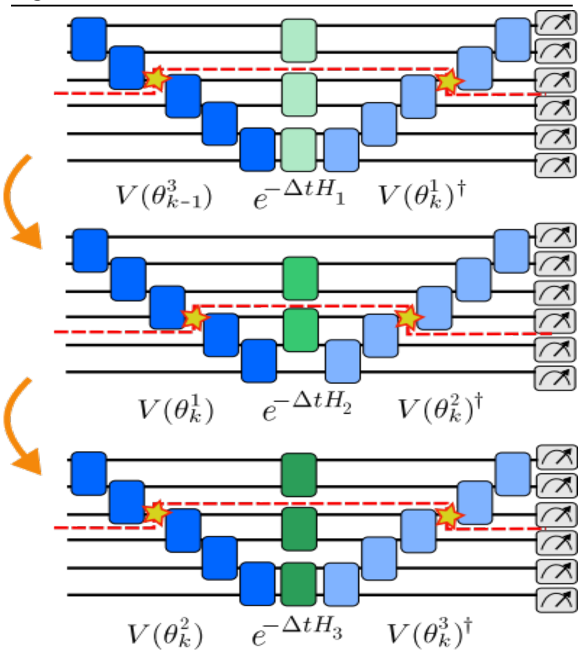

Figure 1: Schematic of the dp-VQD procedure. The Hamiltonian is divided in sub-iterations of p-VQD, where each slice is constructed to be trivially cutable into two or more pieces. The quantum dynamic is reproduced by the variational ansatze V(θ) trained for each sub-iteration.