Emergent Coupling Based Ansatz evaluated on a Superconducting Quantum Processor

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Variational quantum algorithms are among the most promising tools for exploiting noisy intermediate-scale quantum (NISQ) devices, yet their performance critically depends on the choice of ansatz [1]. In this work, we introduce and experimentally validate the Emergent Coupling Based Ansatz (ECBA), a physically motivated variational ansatz for efficient quantum simulation on NISQ devices [2,3]. The ECBA is based on a renormalization group flow identification of dominant effective couplings, resulting in shallow circuits that capture the essential entanglement structure of strongly correlated and disordered quantum systems. We implement the ECBA within a variational quantum eigensolver framework on superconducting quantum processors and benchmark it on disordered spin-chain models. Using error mitigation techniques [4], we study systems of up to 30 qubits and observe excellent agreement with exact results, achieving experimental fidelities up to 98%. In simulations we reach fidelities of at least 99% for up to 120 qubits [2]. Furthermore, we demonstrate that the ECBA can be efficiently embedded on hardware with two-dimensional square lattice connectivity. Compared to commonly used variational ansatz schemes, the ECBA achieves significantly higher accuracy at reduced circuit depth, establishing it as a scalable approach for quantum simulations on current quantum devices.

References

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[3] A. Joch, K. Lively, B. Fauseweh, in preparation.
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Figures

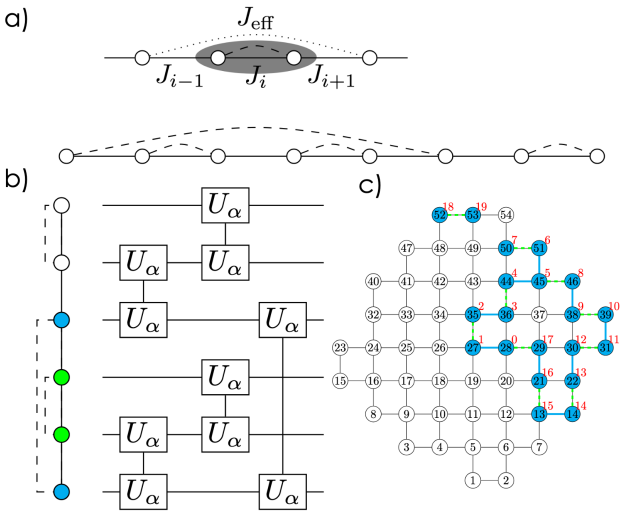

Figure 1: a) Renormalization group flow, b) ECBA circuit, c) hardware embedding

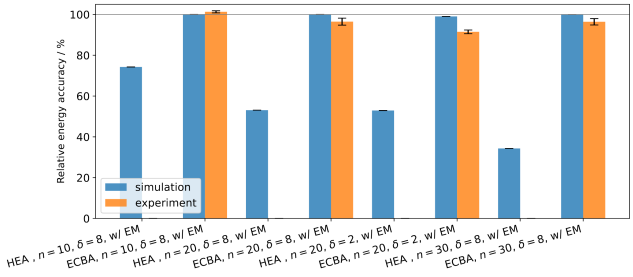

Figure 2: Simulation (blue) and experimental (orange) results for ECBA in comparison to hardware efficient ansatz (HEA)