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Title: Quantum Simulation of the Ground State of Many-Body Systems

Abstract: Simulating the ground state of many-body systems is one of the key challenges in physics and material science. Many features of the matter, such as chemical bonds and electronic structures, are fully explained by the ground state picture. However, due to the exponential growth of the Hilbert space simulating the ground state of a general many-body system is intractable on a classical computer. Many approximation methods, such as Density Functional Theory and Matrix Product States, have been developed to tackle this problem. However, all these methods are limited in their applications and the only true simulation is to use a quantum simulator. Thanks to recent advances in quantum technologies, quantum simulators have been developed in various platforms, including superconducting and semiconducting devices, cold atoms, trapped ions and photonics. Here, we focus on simulating the ground state of many-body systems on both digital and analog quantum simulators. For digital simulators, we propose variational methods through an interacting interface between a quantum circuit and a classical optimizer, the so-called Variational Quantum Eigensolver (VQE). Our focus is to scale up the VQE methods to large system sizes by improving the classical optimizer. For analog simulators, we use adiabatic dynamics to prepare the ground state of certain Hamiltonian. Unlike the VQE, the adiabatic preparation of the ground state needs independent certification. We provide various methods to certify such analog simulators to see whether they really do the tasks which they have been designed for.