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Lipkin model analysis with variational quantum eigensolver

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Even though the quantum computing with fault tolerance is still a rather distant target, we are now entering a significant new era in developing quantum technology. In this circumstance, Noisy Intermediate-Scale Quantum Computing (NISQ) is defined by Preskill in 2018[1]. NISQ algorithms try to avoid deep circuits and utilize quantum advantages, which are efficiently preparing quantum states. NISQ devices will be useful for exploring many-body quantum physics and also lead to other useful applications. Variational quantum eigensolver (VQE) was proposed as a first practical algorithm for NISQ and the ground-state molecular energy for He-H^+ was calculated [2]. VQE is a hybrid algorithm that uses a variational method and combines quantum and classical computations in order to obtain the minimum eigenvalue of the Hamiltonian H of a given system.

Lipkin model is formulated [3] in order to investigate the validity of varied methods and formalisms proposed for calculating many-body systems. This model is also simple enough to be solved exactly. Therefore, we have adopted this model as a benchmark test for the VQE method. To carry out the VQE algorithm successfully we need to choose variational trial functions, i.e., ansatze appropriately. We tried out two kinds of ansatze: unitary coupled-cluster (UCC) ansatz [4] and structure learning (SL) ansatz [5]. UCC ansatz is often used for analyzing molecular systems and developed from coupled-cluster theory [6]. SL ansatz is a method for simultaneously optimizing the structure and variational parameters of quantum circuits. The calculations were performed with numerical simulations on a classical computer. Consequently, we obtained consistent results between the exact ground-state energies and the energies with UCC and SL ansatze in the Lipkin model.

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Field of your work

Theoretical nuclear physics

Primary author: Mr ASAHI, Chikaoka (Department of Physics, The University of Tokyo)

Co-author: LIANG, Haozhao (RIKEN)

Presenter: Mr ASAHI, Chikaoka (Department of Physics, The University of Tokyo)

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