Improving success probability of imaginary-time evolution on a quantum computer

Due to the exponential decay feature of high-energy states, quantum algorithms based on the imaginary time evolution (ITE) method have been actively studied. We propose a probabilistic way to realize the action of the ITE operator by introducing auxiliary qubits. This is called the probabilistic ITE (PITE) method. The advantage of the PITE method over other types of ITE methods on quantum computers is that it does not require repeated measurements of the quantum circuit to obtain the next imaginary time step. However, the stochastic nature of the PITE method also brings drawbacks. That is, the probability of success (the probability of obtaining the state in which the ITE operator is acted upon) decreases exponentially as the imaginary time increases. Here, we use a technique called quantum amplitude amplification to address this undesirable property. The quantum circuit developed for PITE combined with quantum amplitude amplification successfully reduces the depth of the circuit and improves the probability of success. We present simulation results using the proposed technique and a discussion of the computational overhead of the amplifier circuit.