Hessisches Kompetenzzentrum
für Hochleistungsrechnen

The Measurement-Based Quantum Eigensolver



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Clusters
Lichtenberg II Cluster Darmstadt

Additional Software
Qiskit

Institute
Quantum Computing

University
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Introduction

In this project, our primary focus is to validate and benchmark the performance of a measurement-based variational quantum eigensolver (MB-VQE) via comprehensive simulations on classical hardware. Measurement-based quantum computing (MBQC) operates as a universal quantum computing paradigm, whereby information processing is achieved through localized quantum measurements on a highly entangled resource state. This MBQC scheme, specifically suited for currently inaccessible photonic platforms, offers a distinctive alternative to gate-based quantum computing. In contrast to the prevalent gate-based quantum hardware, which struggles with the considerable constraint of gate depth, MBQC has recently emerged as a viable solution to mitigate these demanding gate depth requirements. Our project goals include conducting empirical assessments to determine the efficacy of MB-VQE as a depth-reducing scheme. The variational quantum eigensolver (VQE) is a quantum-classical hybrid algorithm that can find approximate solutions to the Hamiltonian ground state problem. This NISQcompatible approach can be applied to complex optimization problems in various fields, including quantum chemistry. By simulating the behavior of the MBQC-based variational quantum eigensolver, we can evaluate its performance and gain valuable insights into its capabilities. Furthermore, through comprehensive and methodical benchmarking, we will investigate the inherent advantages and limitations associated with the MB-VQE approach, thereby enriching our understanding of its practical application in addressing computationally intensive problems.

Methods

To achieve our project goals, we conducted simulations on classical hardware, utilizing well-established Python libraries for noise-free quantum computation modeling. Simulating MBQC poses a notable challenge due to its memoryintensive nature, as the dimensions of the quantum state vector exponentially scale with the number of qubits involved. To mitigate this challenge, we implemented a qubit recycling technique, reducing memory usage by restricting the absolute qubit count per computation step. For the optimization, we utilized the L-BFGS (Limited-memory Broyden-Fletcher Goldfarb-Shanno) algorithm.

Results

Our devised measurement-based quantum computing (MBQC) method exhibits broad applicability, successfully addressing various Hamiltonians, including molecular Hamiltonians (H2 and H4), the XY-model, and the Schwinger model. This showcases the versatility of our MBQC approach, demonstrating its potential for solving diverse quantum systems and problems. However, it is worth noting that our ansatz is not tailored for specific problems. While it demonstrates promising outcomes across different Hamiltonians, further refining and customizing the method will be necessary to apply it to practical challenges on actual quantum hardware effectively.

Discussion

In this project, we validated and benchmarked the performance of a measurementbased variational quantum eigensolver (MB-VQE) through simulations on classical hardware. Our simulation approach utilized noise-free quantum computation modeling in Python, and we addressed the memory-intensive nature of MBQC by implementing qubit recycling. The results showed that our MBQC method successfully addressed a range of Hamiltonians, including molecular Hamiltonians (H2 and H4), the XY-model, and the Schwinger model. This highlighted the versatility of MBQC in the context of NISQ algorithms. In future projects, we want to explore how the statistics of the intermediate measurements might be utilized to mitigate hardware errors.

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