A Simulating Quantum Systems with NWQ-Sim on HPC

In-Saeng Suh[1] and Ang Li[2]
[1] National Center for Computational Sciences, Oak Ridge National Laboratory, Oak Ridge, TN , USA
[2] Physical and Computational Sciences Directorate, Pacific Northwest National Laboratory, Richland, WA , USA

Summary

NWQ-Sim is a cutting-edge quantum system simulation environment designed to run on multi-node, multi-CPU/GPU heterogeneous HPC systems

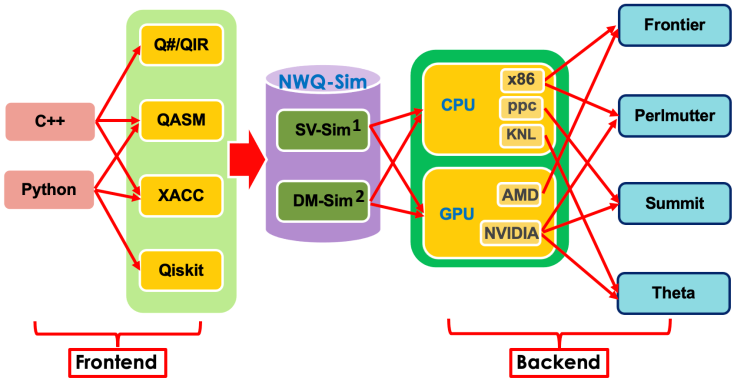
In this work, we provide a brief overview of NWQ-Sim and its implementation in simulating quantum circuit applications, such as the transverse field Ising model.

1. **Demonstrate how NWQ-Sim can be used to examine the effects of errors that occur on real quantum devices using a combined device noise model.**
2. **Illustrate this with the variational quantum eigensolver (VQE) for the Ising model.**

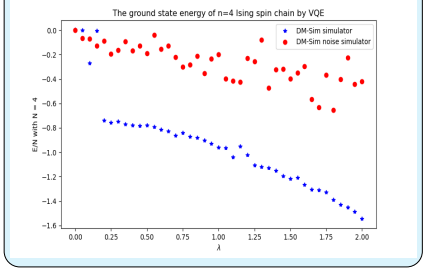
➔ **NWQ-Sim's performance is comparable to or better than alternative simulators.**

We conclude that NWQ-Sim is a useful and flexible tool for simulating quantum circuits and algorithms, with performance advantages and noise-aware simulation capabilities.

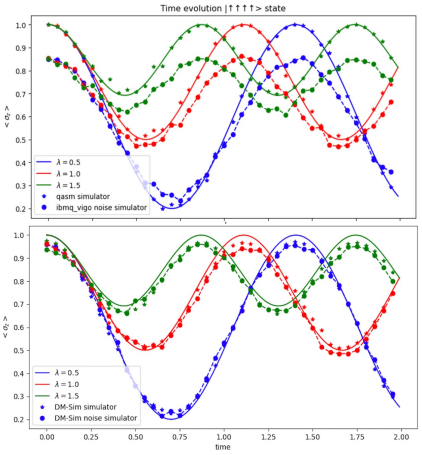
NWQ-Sim Framework



Noise/VQE[5]



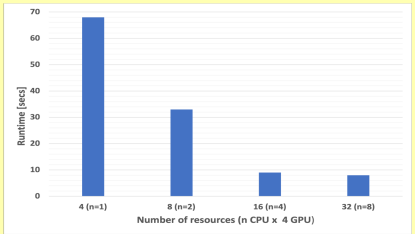
Time Evolutions



Background

1. **Limited availability of quantum computing resources such as those provided by IBMQ or Azure Quantum means that many users share them, resulting in long waiting times for quantum resource allocation.**
2. **Since parameterized variational circuits are typically deep, as a result, the depth of these circuits can easily exceed the maximum gate allowance of NISQ devices due to their short coherence time.**
3. **Current quantum computers are not quantum-error-correction (QEC) protected, resulting in high error rates. Consequently, simulations are necessary for validating quantum algorithms and debugging circuits**

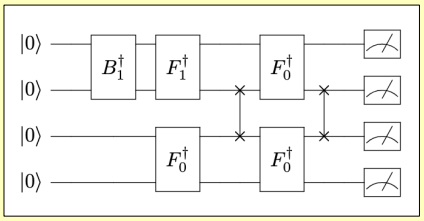
QASMBench



SV-Sim simulator benchmark on Summit (QASMBench[3] – 12 Quantum Circuits)

Quantum System

Transverse Field Ising Model[4] (n=4)



***F*: Fourier Transformation**
***B*: Bogoliubov Transformation**
x-x: Jordan-Wigner Transformation

Importing NWQ-Sim

```
#=============================================
from qiskit_nwqsim_provider import NWQSimProvider
#---------------------------------------------
nwqsim = NWQSimProvider('SVSimSimulator')
backend = nwqsim.backends['svsim_gpu']
#=============================================
```

```
nwqsim = NWQSimProvider('DMSimSimulator')
backend = nwqsim.backends['dmsim_gpu']
#=============================================
```

References

[1] Li, Ang and Krishnamoorthy, Sriram, SV-Sim: Scalable PGAS-based State Vector Simulation of Quantum Circuits, Proc. of the Int. Conf. for High Performance Computing, Networking, Storage and Analysis, 2021
[2] Li, Ang and Subasi, Omer and Yang, Xiu and Krishnamoorthy, Sriram, Density Matrix Quantum Circuit Simulation via the BSP Machine on Modern GPU Clusters, Proc. of the Int. Conf. for High Performance Computing, Networking, Storage and Analysis, 2020
[3] Li, Ang and Stein, Samuel and Krishnamoorthy, Sriram and Ang, James, QASMBench: A Low-Level Quantum Benchmark Suite for NISQ Evaluation and Simulation, ACM Transactions on Quantum Computing, Volume 4, Issue 2, Article No.: 10, pp 1–26, 2023
[4] Cervera-Lierta, Alba, Exact {I}sing model simulation on a quantum computer, Quantum, 2:114, December 2018
[5] Potnuru, L, Finding the ground state of the transverse Ising model,github.com/LohitPotnuru/TransverseIsingModelQiskit, 2021

This research used resources of the Oak Ridge Leadership Computing Facility at the Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725. This research used resources of the National Energy Research Scientific Computing Center (NERSC), a U.S. Department of Energy Office of Science User Facility located at Lawrence Berkeley National Laboratory, operated under Contract No. DE-AC02-05CH11231 using awards ERCAP0023224 and ERCAP0023053