Rogues Gallery VIP - Quantum Computing - Fall 2023

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Semester Overview

This semester focused on preparing the team to continue the work in deep reinforcement-learning covered in the Spring 2023 semester. In particular, the team focused on (1) environment setup and literature, (2) implementation of a basic quantum algorithm for practice, (3) planning ML model architecture for noise reduction.

Environment Setup and Onboarding Resources

Environment setup involves logging into the cluster and installing dependencies for a conda environment on the cluster. This allows users to run simulations on the cluster.

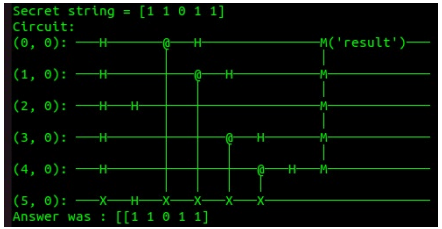
Created dockerfile for environment setup so future onboarding is smoother. Removes need for downloading dependencies.

Practice Implementation

Studied theory behind Bernstein-Vazirani and Deutsch-Jozsa. Implemented Bernstein-Vazirani using cuquantum.

Bernstein–Vazirani Algorithm

Implementation using custatevec. Set up input qubits, function oracle, and measurement. Able to get ~32 qubits.

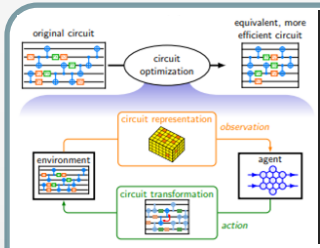


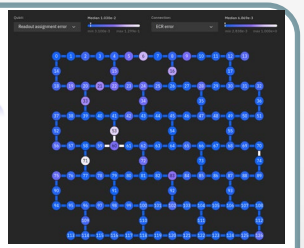
Noise Model

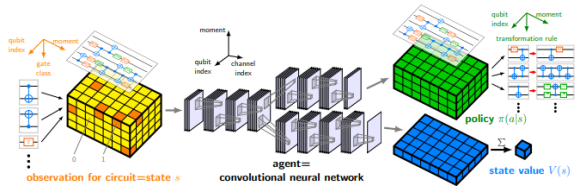
Able to add depolarization, bit flip, phase flip, and amplitude damping to circuits. Still need to work out how to make these correspond to the ibm_sherbrooke calibration data.

Planned Model Architecture

- Train a neural network model on the best circuit configurations to reduce the noise of the circuit
- Utilize reinforcement learning algorithms to train on circuit "swaps"
  - Model would receive rewards based on custom cost function
  - Agent (model) takes actions and attempts swaps for improvement
- Test genetic models for similar purpose to test candidate solutions and pick optimal solutions
  - Lightweight, more feasible given computing resources available







Future Work

- Continue implementing noise model to simulate ibm_sherbrooke
- Need ~1000 noise simulations for equivalent circuits
- Continue implementing/testing gate swapping logic
- Need inexpensive reward function (basically non neural net) that estimates noise of a given circuit
- Investigate more ML algorithms for optimal circuit constructions
- Expanding our work to utilize multiple GPUs, pushing qubit number and circuit depth limits further

References

1. https://docs.nvidia.com/cuda/cuquantum/latest/cutensornet/overview.html
2. https://quantumai.google/cirq/simulate/noisy_simulation
3. https://nvidia.github.io/cuda-quantum/latest/using/python.html
4. Aseguinolaza, U., Sobrino, N., Sobrino, G., Jornet-Somoza, J., & Borge, J. (2023, June 30). *Error estimation in current noisy quantum computers*. arXiv. https://arxiv.org/pdf/2302.06870v2.pdf
5. Fösel, T., Niu, M. Y., Marquardt, F., & Li, L. (2021, March 13). Quantum circuit optimization with deep reinforcement learning. arXiv.org. https://arxiv.org/abs/2103.07585