Developing a Hybrid Methodology for Solving Quantum Problems

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Abstract

In 1982, Feynman famously described the exponential scaling issue that is faced by any classical computing method that attempts to simulate a quantum system [1]. This is not only a challenge for simulators, but also for theorists who study quantum many-body system dynamics. For example, exploring multi-qubit entanglement is important for a fundamental understanding of quantum mechanics as well as for building large scale quantum computers [2]. A growing list of analogues between classical computing and quantum computing are being discovered in areas including machine learning [3, 4] and tensor networks [5]. We explore how distributed computing systems can be used to combine simulation approaches based on these analogues and enable more resource-optimized simulations. We contribute a framework for expressively implementing distributed quantum systems simulations in code. Our framework executes simulations using resources traditionally used for distributed cloud machine learning and data processing. We show how it can be used to analyze the performance of different simulation approaches and automatically suggest the best approaches to use for particular problems.

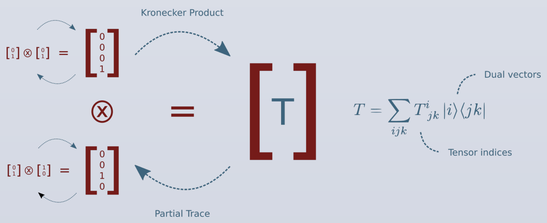
Objectives

We were interested in implementing a number of quantum computing simulators as cloud microservices that could work together using different methods to simulate quantum algorithms. We also supported the delegation of subtasks to real IBM quantum processors Tenerife, Yorktown and Melbourne [7]. Our goals were to:

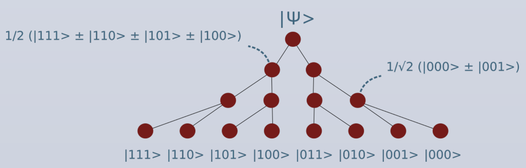
- Explore opportunities for optimizing quantum simulations at each layer of the technology stack
- Support hybrid algorithms that use a mixture of classical and quantum backends
- Provide a repeatable and scalable approach for optimally running hybrid algorithms

Simulators

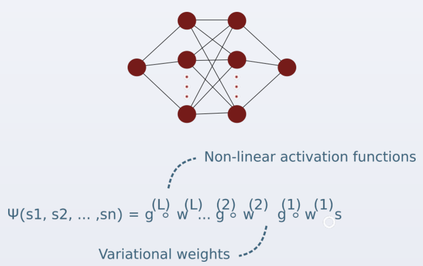
Tensor Network Simulator [8]



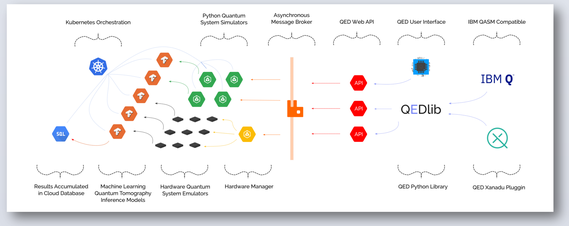
Binary Simulator



Neural Quantum State Simulator [9]



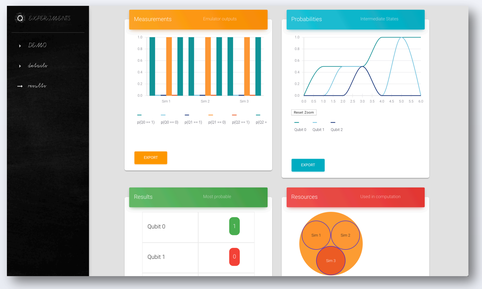
Environment

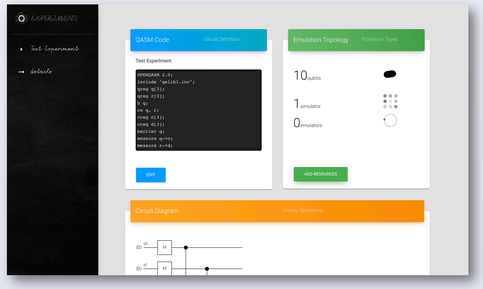


- Scalable hybrid quantum-classical cloud environment
- Eventing pattern enables asynchronous distributed parallelism
- Pools of simulators perform algorithms in parallel with actual quantum processors

Interface

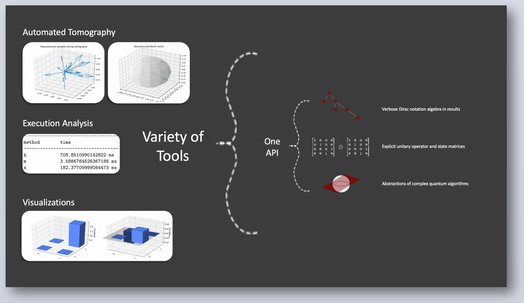
- React based web application with dashboard, experiment configuration and results
- Web based OpenQASM editor and parser
- Scalable RESTful web API layer

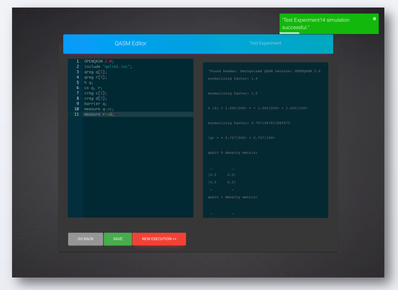




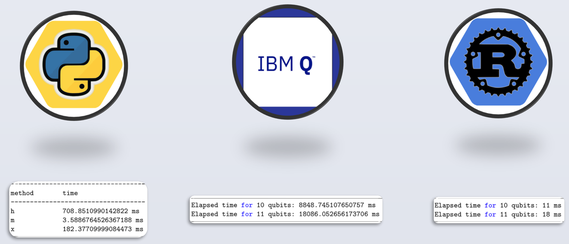
Programming

- New Python simulation library with verbose readout and full solutions in Dirac notation
- New efficient Rust simulation library
- OpenQASM compatible





Example Results



Running the counterfeit coin benchmark problem in three simulators Easily demonstrates their unique strengths:

- Most verbose problem and informative output with the new
- Python simulator
- Most features, options, visualizations using IBM's simulator
- Fastest execution using Rust simulator

Acknowledgements

I would like to thank my supervisor Dr. Shohini Ghose for her excellent support and mentorship, and for the incredible opportunity to work on this project with her.

I would also like to recognize Josh Izaac for helping me get involved with Xanadu as I jumped into the world of open source quantum computing software.

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