Google Cloud

Hello Worlds with Cirq

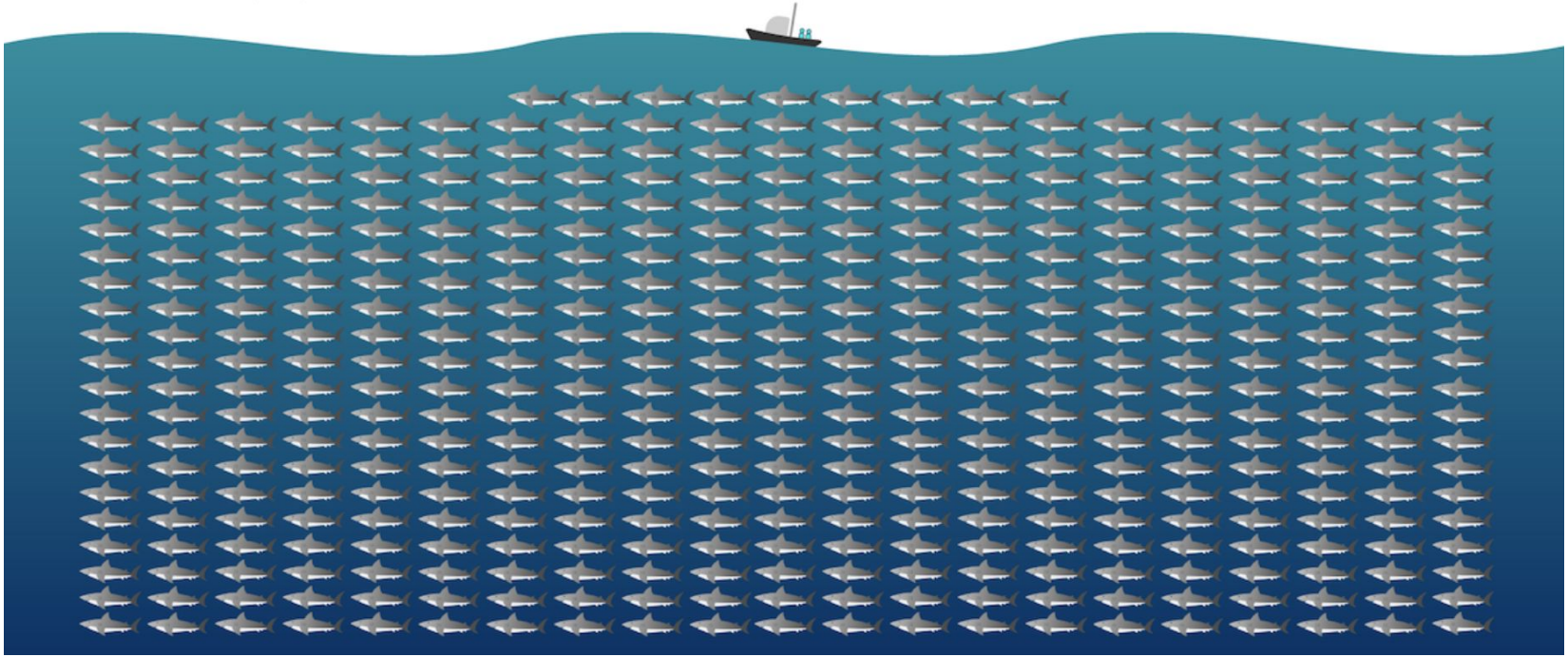
Cloud Quantum Computing

What problems am I working on now?

How Big is 40 exabytes?

Genomics projects will generate 40 exabytes of data in the next decade.

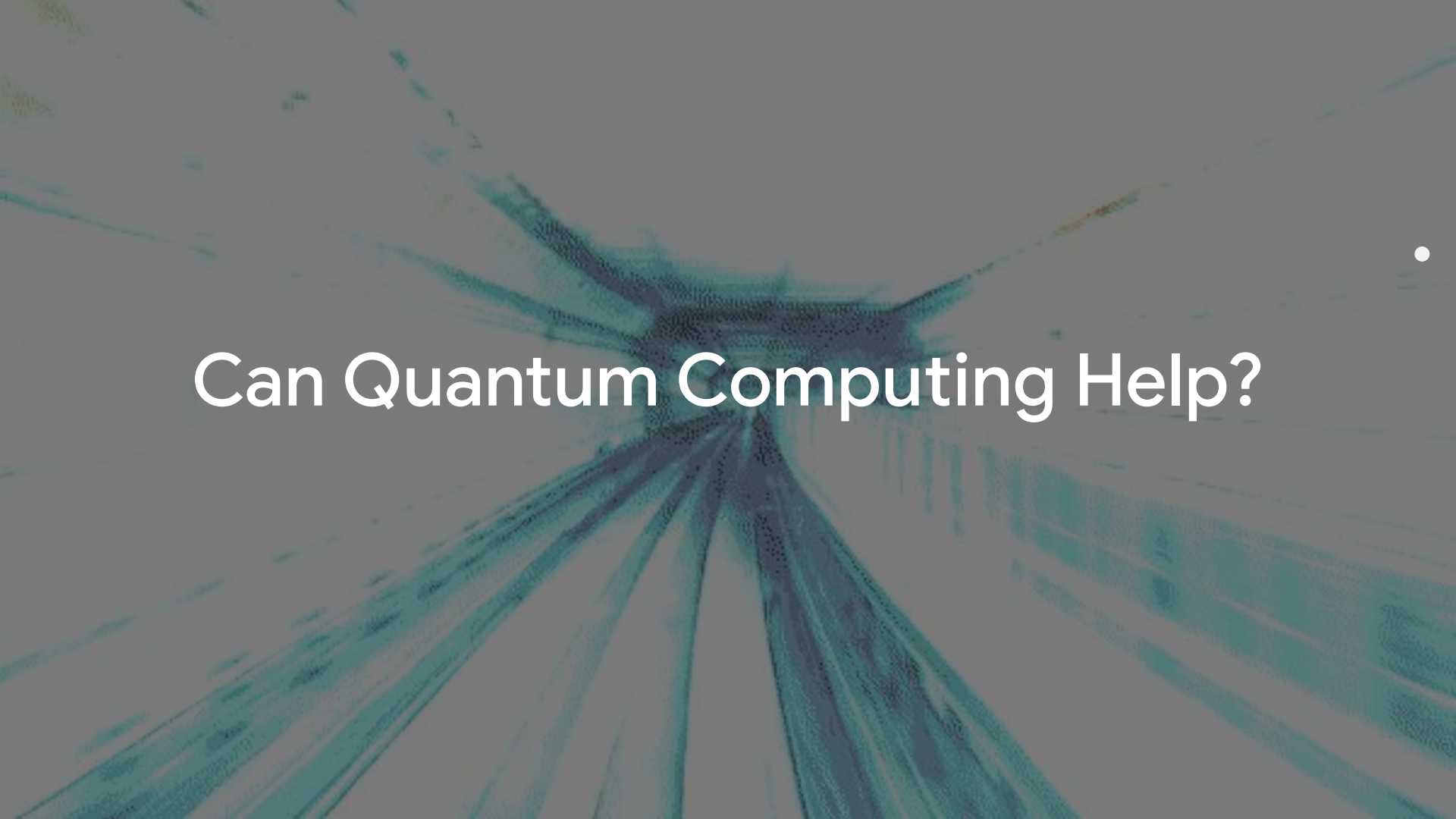
Each shark = 100,000,000 GB of data



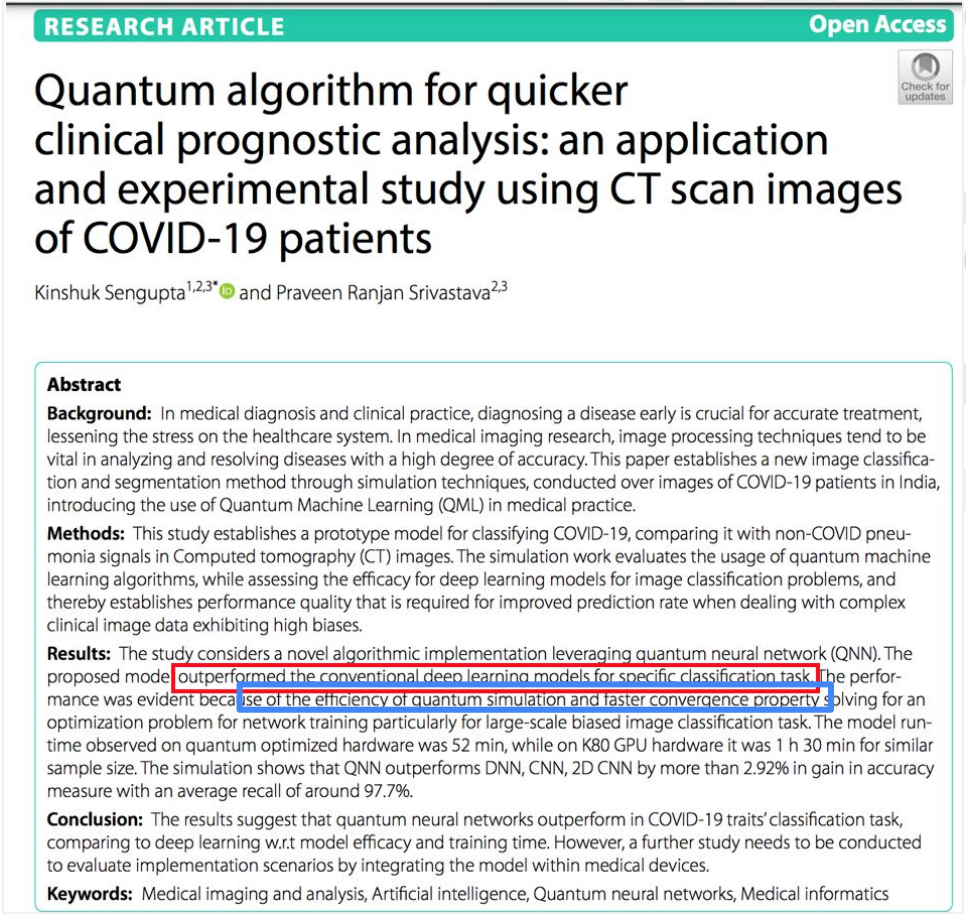
https://www.genome.gov/about-genomics/fact-sheets/Genomic-Data-Science

Problem Space

- Genomic Data Volumes
- N x N computational Complexity
- Speed up data pipelines


Can Quantum Computing Help?

YES!



RESEARCH ARTICLE Open Access

Quantum algorithm for quicker clinical prognostic analysis: an application and experimental study using CT scan images of COVID-19 patients

Kinshuk Sengupta[1,2,3*] and Praveen Ranjan Srivastava[2,3]

Abstract

Background: In medical diagnosis and clinical practice, diagnosing a disease early is crucial for accurate treatment, lessening the stress on the healthcare system. In medical imaging research, image processing techniques tend to be vital in analyzing and resolving diseases with a high degree of accuracy. This paper establishes a new image classification and segmentation method through simulation techniques, conducted over images of COVID-19 patients in India, introducing the use of Quantum Machine Learning (QML) in medical practice.

Methods: This study establishes a prototype model for classifying COVID-19, comparing it with non-COVID pneumonia signals in Computed tomography (CT) images. The simulation work evaluates the usage of quantum machine learning algorithms, while assessing the efficacy for deep learning models for image classification problems, and thereby establishes performance quality that is required for improved prediction rate when dealing with complex clinical image data exhibiting high biases.

Results: The study considers a novel algorithmic implementation leveraging quantum neural network (QNN). The proposed model outperformed the conventional deep learning models for specific classification task. The performance was evident because of the efficiency of quantum simulation and faster convergence property solving for an optimization problem for network training particularly for large-scale biased image classification task. The model runtime observed on quantum optimized hardware was 52 min, while on K80 GPU hardware it was 1 h 30 min for similar sample size. The simulation shows that QNN outperforms DNN, CNN, 2D CNN by more than 2.92% in gain in accuracy measure with an average recall of around 97.7%.

Conclusion: The results suggest that quantum neural networks outperform in COVID-19 traits' classification task, comparing to deep learning w.r.t model efficacy and training time. However, a further study needs to be conducted to evaluate implementation scenarios by integrating the model within medical devices.

Keywords: Medical imaging and analysis, Artificial intelligence, Quantum neural networks, Medical informatics

article

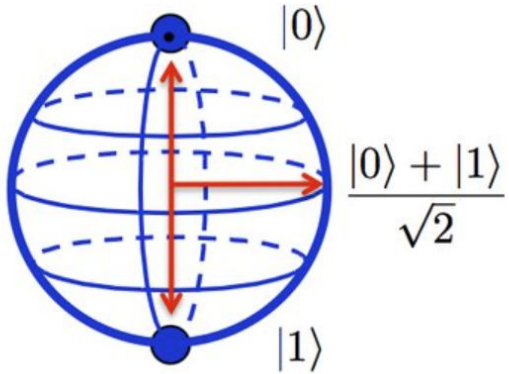
What is Quantum Computing?

“

Quantum computing is **a type of computation that harnesses the collective properties of quantum states**, such as superposition, interference, and entanglement, to perform calculations.”

Wikipedia

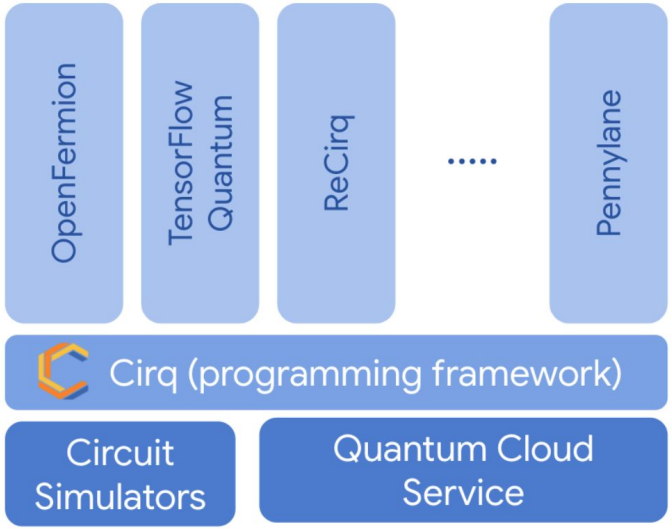
A qubit is the basic unit of quantum information. It is a two-state quantum-mechanical system, which can display information based on the principles of **quantum mechanics**.



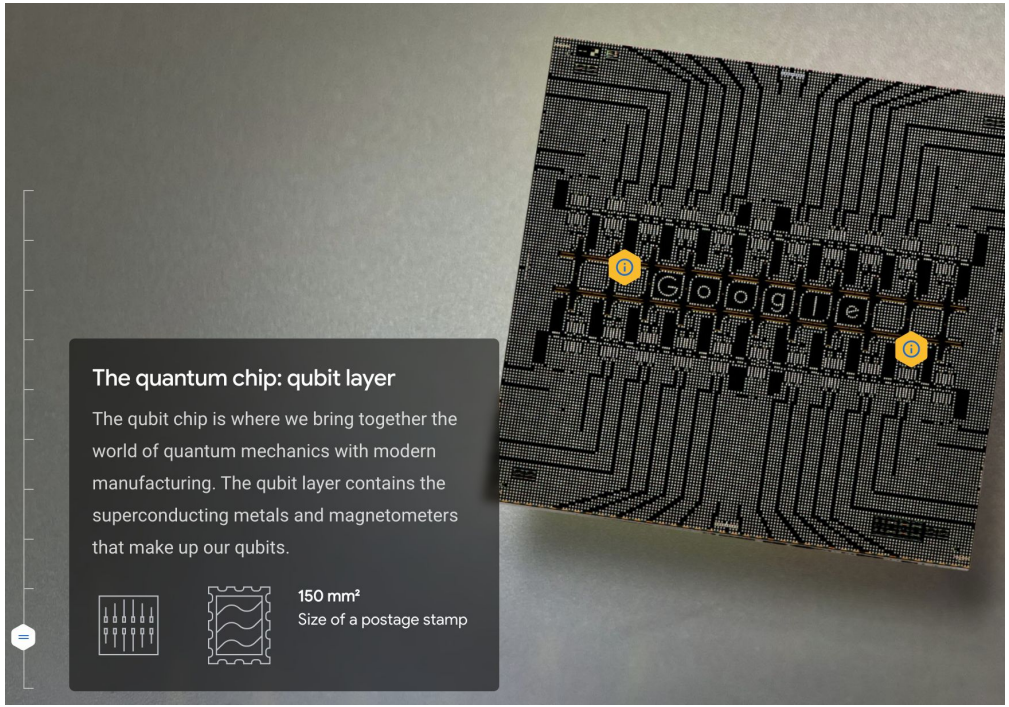
https://www.zmescience.com/science/physics/quantum-computing-regulating-device-05032015/

What is Available on Google Cloud?

- Libraries (TensorFlow Quantum and more)
- Programming Framework (Cirq)
- Quantum Circuit Simulators
- Quantum Hardware (QCS)



What is a QPU?



A quantum processing unit (QPU), is a physical chip that contains a number of interconnected **qubits**.

It is the foundational component of a full quantum computer, which includes the housing environment for the **QPU**, the control electronics, and many other components.

Image from interactive presentation "Discover the Quantum AI Campus"

Using Cirq

Python-style library to access QPUs on Google Cloud

```
"""Creating a circuit."""
# Define three qubits.
a = cirq.NamedQubit("a")
b = cirq.NamedQubit("b")
c = cirq.NamedQubit("c")

# Define a list of operations.
ops = [cirq.H(a), cirq.H(b), cirq.CNOT(b, c), cirq.H(b)]

# Create a circuit from the list of operations.
circuit = cirq.Circuit(ops)
print("Circuit:\n")
print(circuit)
```

```
Circuit:

a: ─────H──────────────────

b: ─────H─────@─────H──────
              │
c: ───────────X────────────
```

01

Demo
Using Cirq on Colab - Setup

Demo Options
(I will pick one from this list)

Cloud Audience

1) Get Started w/GQS

https://quantumai.google/cirq/tutorials/google/start#write_and_run_a_short_quantum_program

2) Cirq basics (run in Colab?)

https://quantumai.google/cirq/tutorials/basics

ML Audience

1) Hello many worlds w/TFQ

https://www.tensorflow.org/quantum/tutorials/hello_many_worlds

2) QCNN using TFQ

https://www.tensorflow.org/quantum/tutorials/qcnn

Google Cloud Processors

CPU

- Compute Processor
- Many options

GPU

- Graphics Processor
- Linear Operations

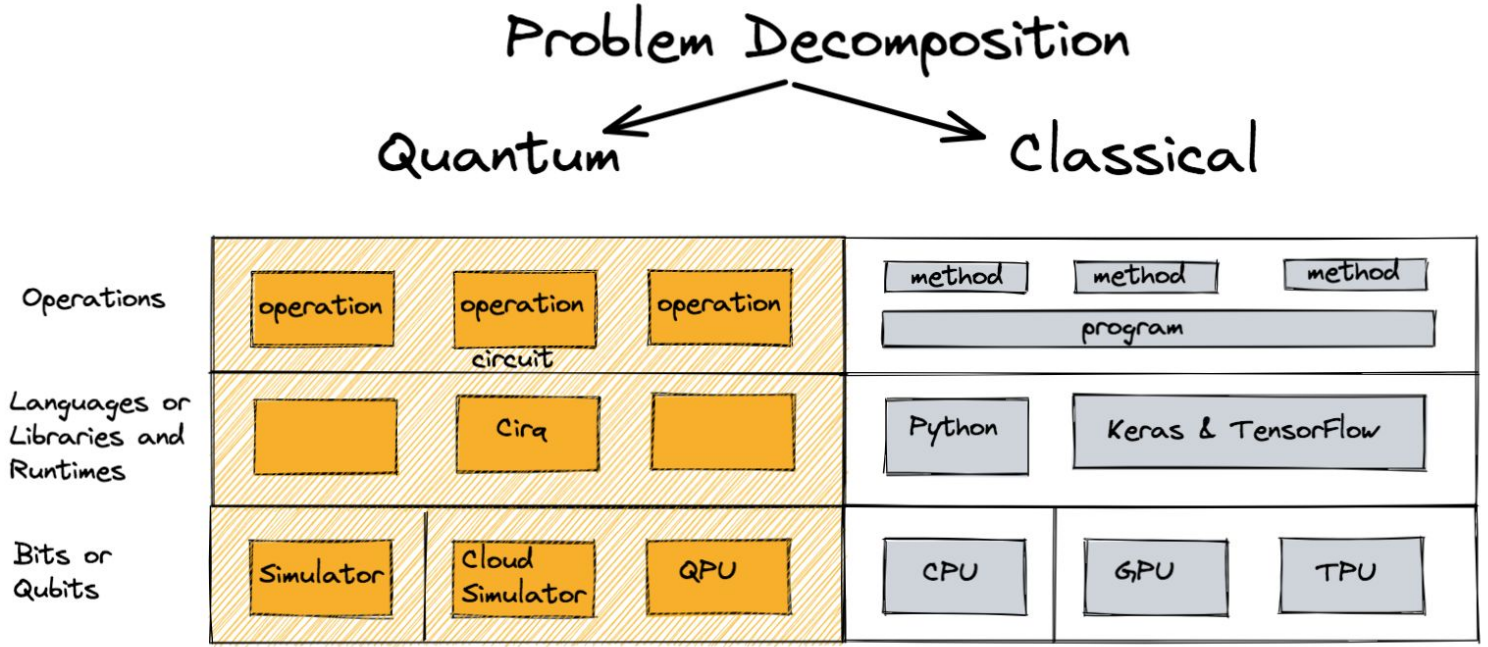
TPU

- Tensor Processor
- Google-only

QPU

- Quantum Processor
- Qubits

Definitions

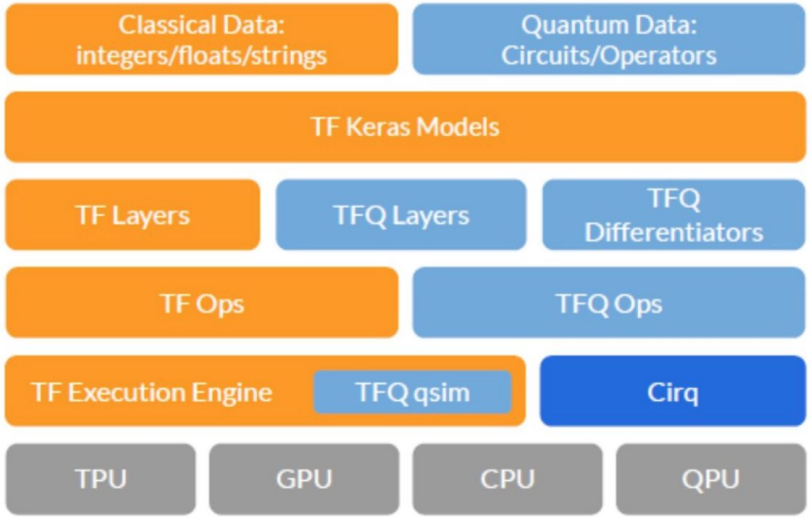


TensorFlow Quantum

Classical data is natively processed by TensorFlow; TFQ adds the ability to process **quantum data**, consisting of both quantum circuits and quantum operators. The next level down the stack is the Keras API in TensorFlow.

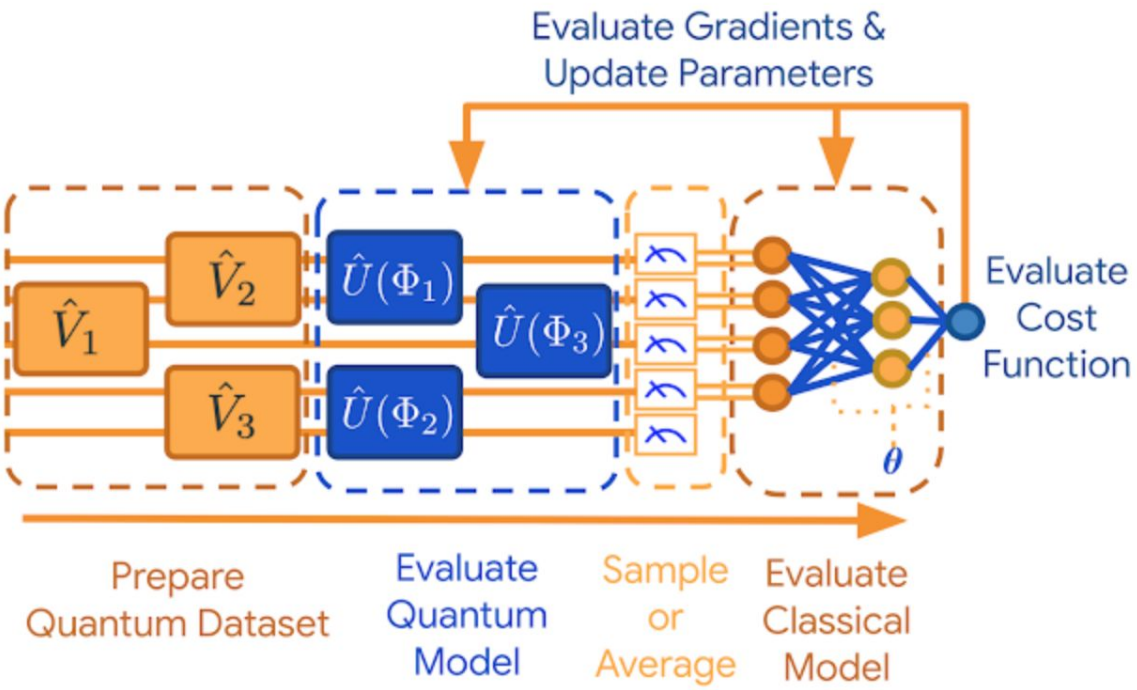
Underneath the Keras model abstractions are the quantum layers and differentiators, which enable **hybrid quantum-classical automatic differentiation** when connected with classical TensorFlow layers.

Underneath these layers and differentiators, TFQ relies on **TensorFlow operations**, which instantiate the dataflow graph.



link

TFQ QCNN



source

TFQ Details

Example runs in 60 minutes on a Google Cloud node of size 'n2-highcpu-80'

1 million
circuit simulations

n 20 qubits
quantum circuit

n gate depth
of 20

blog

In Cirq, there is a strong distinction between Operations and Gates.

An **Operation** is associated with specific qubits and can be put in Circuits.

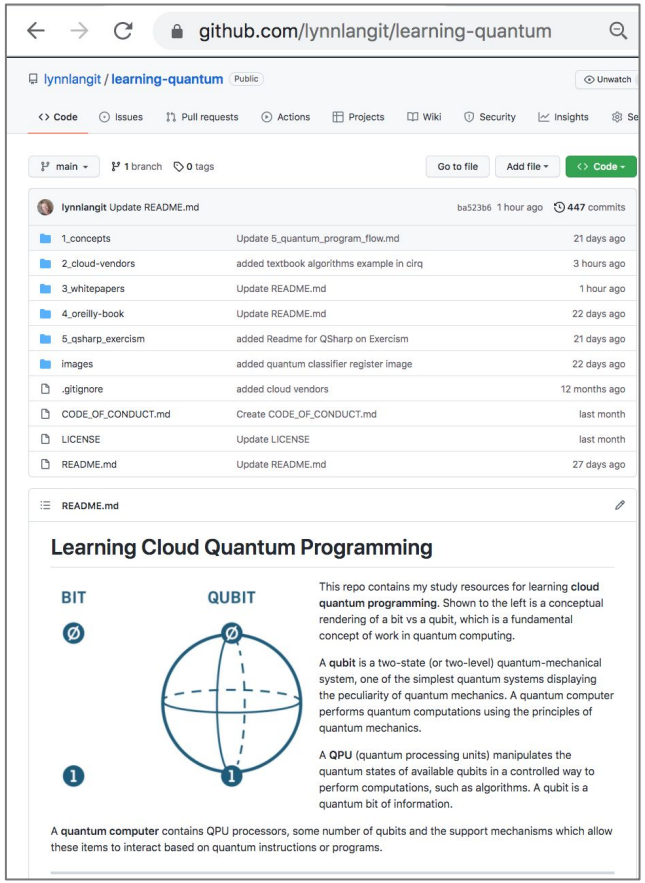
A **Gate** has unspecified qubits, and will produce an operations when acting on qubits.

Practicalities

- Getting your circuit to run on quantum hardware
- Running circuits faster
- Lowering circuit error

Best Practices

Q & A


github.com/lynnlangit/learning-quantum
lynnlangit / learning-quantum
Public
Unwatch
Code
Issues
Pull requests
Actions
Projects
Wiki
Security
Insights
main
1 branch
0 tags
Go to file
Add file
Code
lynnlangit Update README.md
ba523b6 1 hour ago
447 commits
1_concepts Update 5_quantum_program_flow.md 21 days ago
2_cloud-vendors added textbook algorithms example in cirq 3 hours ago
3_whitepapers Update README.md 1 hour ago
4_oreilly-book Update README.md 22 days ago
5_qsharp_exercism added Readme for QSharp on Exercism 21 days ago
images added quantum classifier register image 22 days ago
.gitignore added cloud vendors 12 months ago
CODE_OF_CONDUCT.md Create CODE_OF_CONDUCT.md last month
LICENSE Update LICENSE last month
README.md Update README.md 27 days ago
README.md
Learning Cloud Quantum Programming
BIT
QUBIT
This repo contains my study resources for learning cloud quantum programming. Shown to the left is a conceptual rendering of a bit vs a qubit, which is a fundamental concept of work in quantum computing.
A qubit is a two-state (or two-level) quantum-mechanical system, one of the simplest quantum systems displaying the peculiarity of quantum mechanics. A quantum computer performs quantum computations using the principles of quantum mechanics.
A QPU (quantum processing units) manipulates the quantum states of available qubits in a controlled way to perform computations, such as algorithms. A qubit is a quantum bit of information.
A quantum computer contains QPU processors, some number of qubits and the support mechanisms which allow these items to interact based on quantum instructions or programs.

02

Demo
Using Cirq Hello Worlds