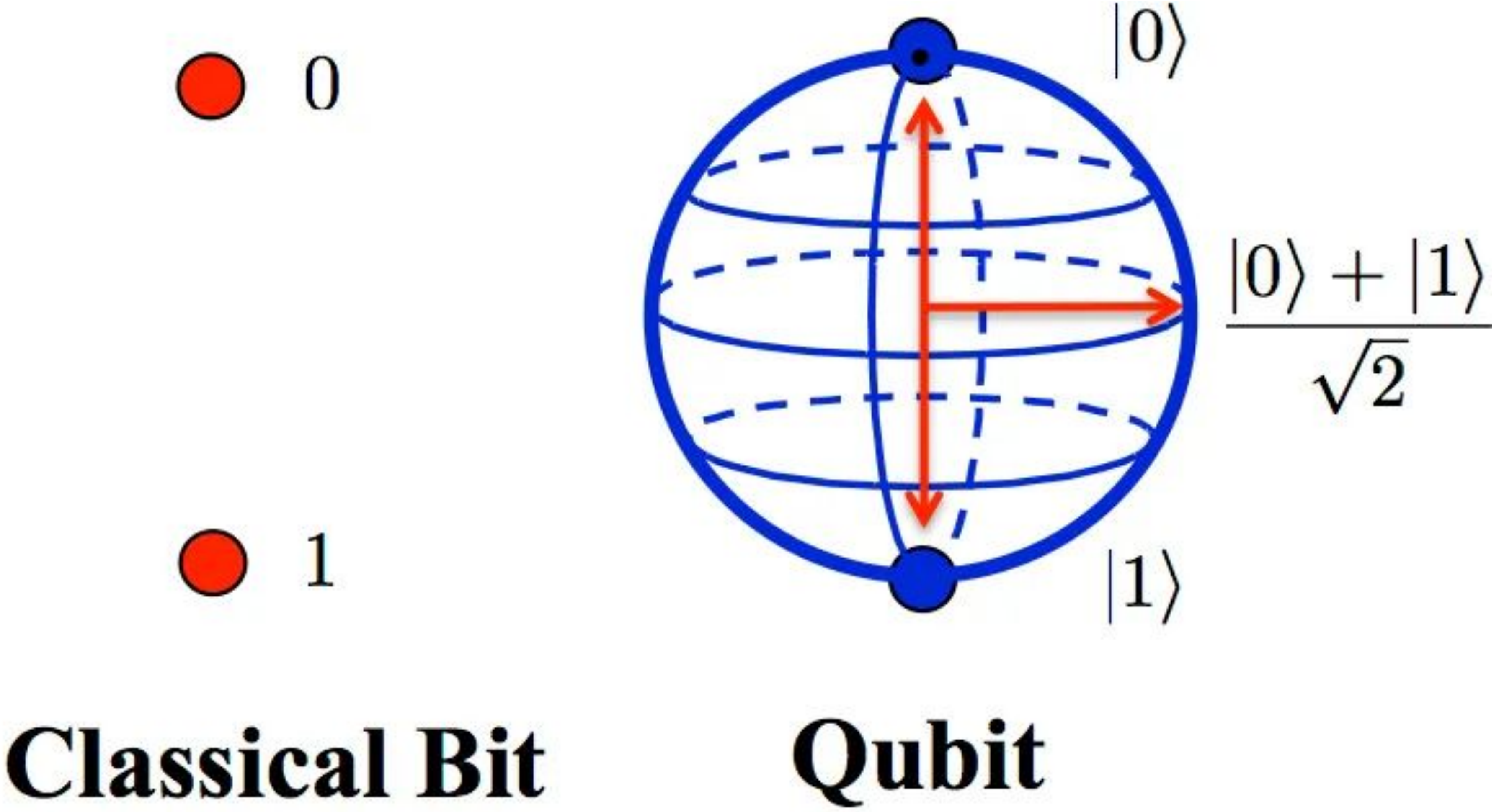
Zurich University
of Applied Sciences

Swiss Python Summit 2024

Quantum Machine Learning: Qiskit 1.X vs PennyLane 0.X

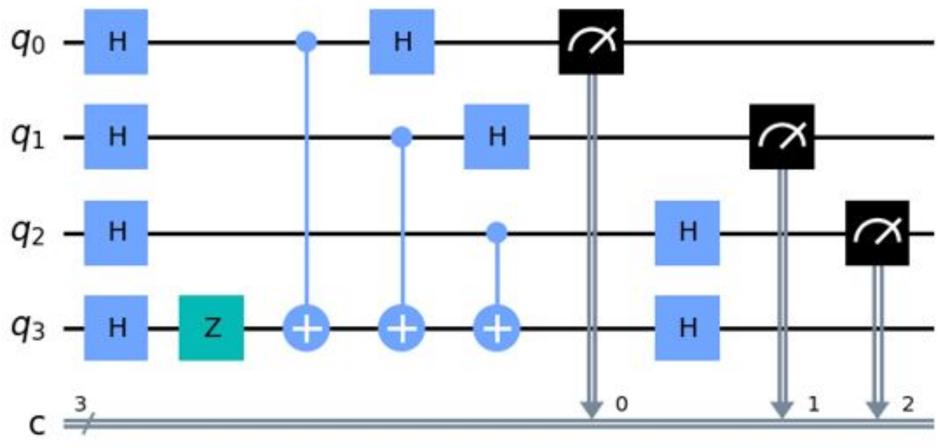
Pavel Sulimov

Quantum Bits

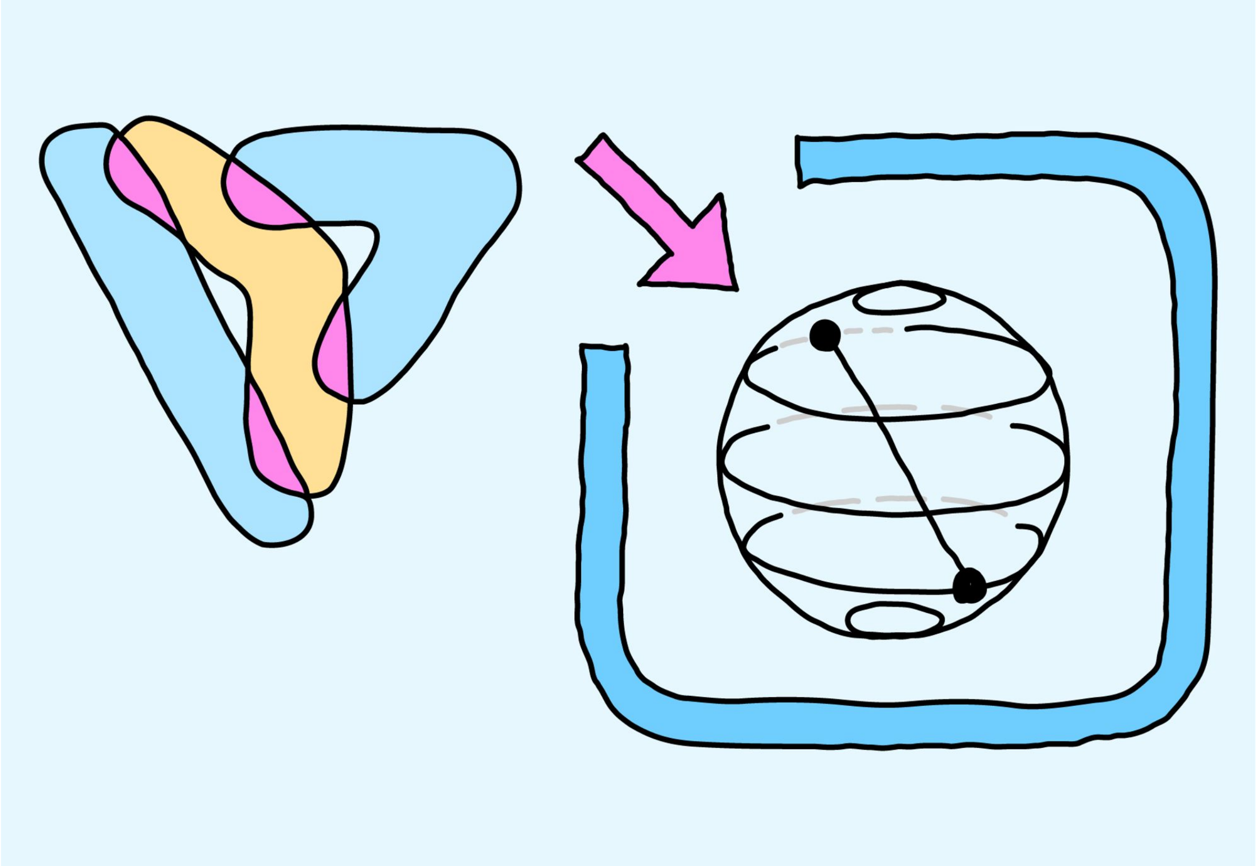


Why to use quantum instead of classical?

- Google has demonstrated in 2019 quantum supremacy: https://blog.google/technology/ai/what-our-quantum-computing-milestone-means/
- In quantum algorithms: parallelism
- In quantum machine learning: more complicated connections due to entanglements resulting in less parameters -> meaning less overfitting
- General possibility of simulating the processes from nature e.g. molecules generation

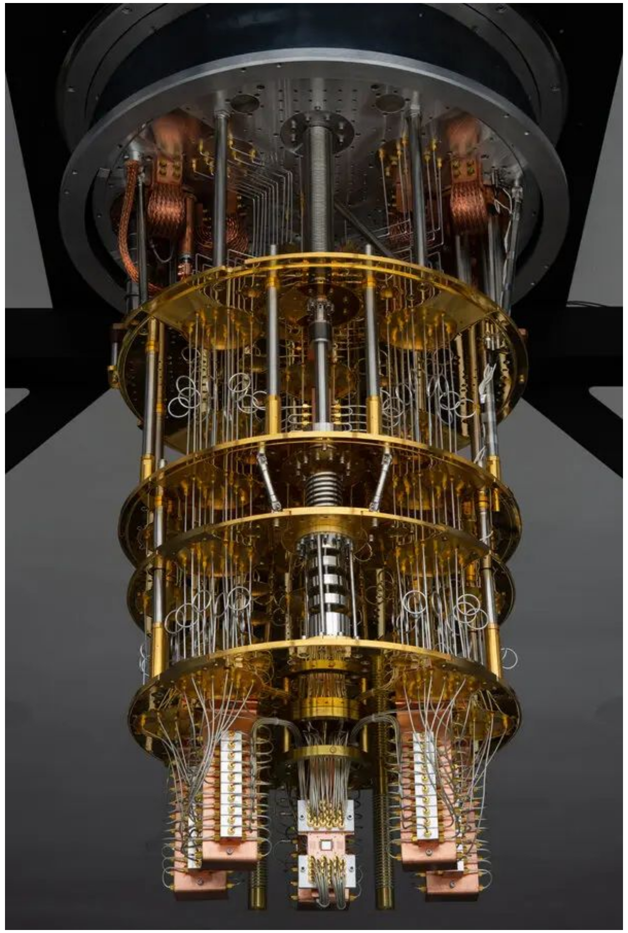


Maths or, even better, machine learning? Pff, Python!



Qiskit by IBM

- General framework for quantum computing, e.g. just executing quantum algorithms
- Has its own machines and has optimization for that with transpilers and built-in error mitigation

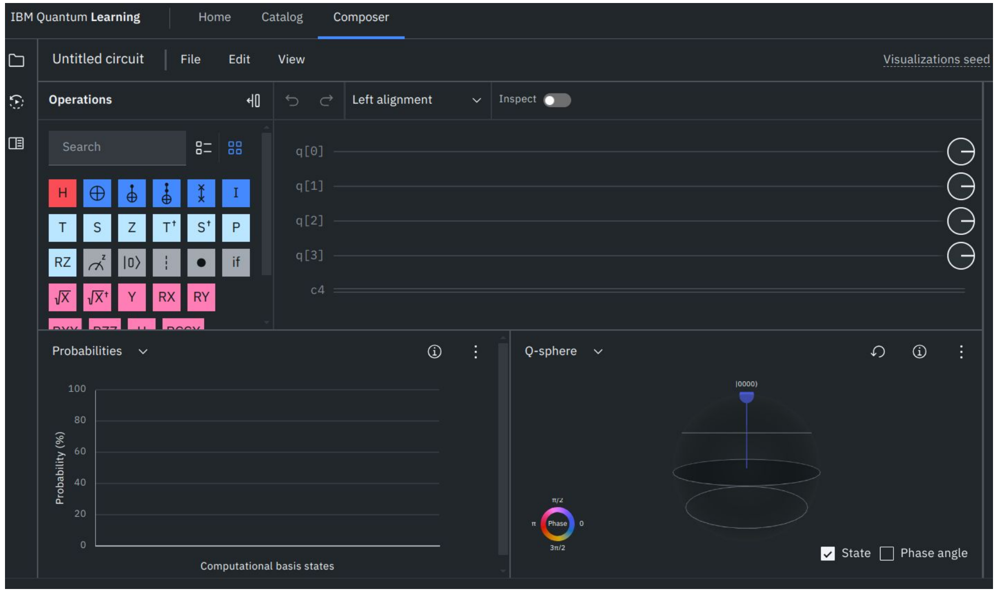


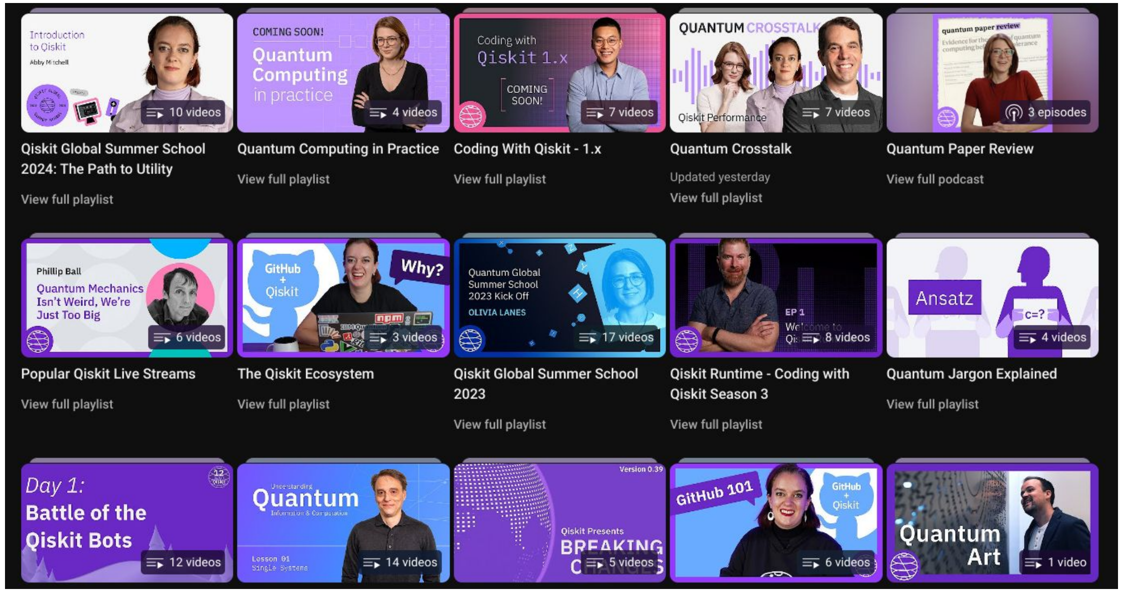
Qiskit v1.2

- Recently (February 2024) got an upgrade to 1.0 with poor backward compatibility and now slowly adapting the algorithms, tutorials etc.
- Has it's own machine learning algorithms and integration with PyTorch etc. that needs to be now verified with latest changes

Qiskit 1.2: good to know

- Main channel of support: Slack
- Has very good tutorials also with videos at YouTube, i.e. for lazy learners
- Has possibility of drawing circuits but NO MORE Lab with Jupyter Notebooks
- You can register and get access to 100+ qubit quantum computer!





PennyLane by Xanadu

- Originally developed for quantum machine learning

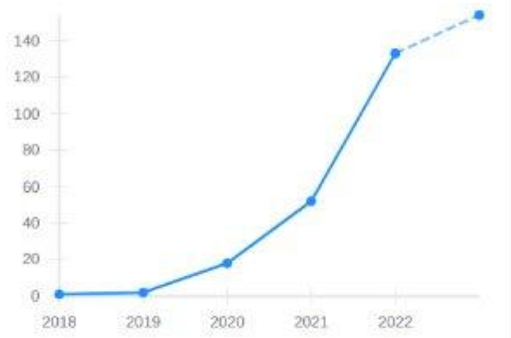
PennyLane: Automatic differentiation of hybrid quantum-classical computations

Ville Bergholm (Xanadu Quant. Tech.), Josh Izaac (Xanadu Quant. Tech.), Maria Schuld (Xanadu Quant. Tech.), Christian Gogolin (Xanadu Quant. Tech.), Shahnawaz Ahmed (Chalmers U. Tech.) Show All(68)

Nov 12, 2018

18 pages
e-Print: 1811.04968 [quant-ph]
View in: ADS Abstract Service

Citations per year



Abstract: (arXiv)
PennyLane is a Python 3 software framework for differentiable programming of quantum computers. The library provides a unified architecture for near-term quantum computing devices, supporting both qubit and continuous-variable paradigms. PennyLane's core feature is the ability to compute gradients of variational quantum circuits in a way that is compatible with classical techniques such as backpropagation. PennyLane thus extends the automatic differentiation algorithms common in optimization and machine learning to include quantum and hybrid computations. A plugin system makes the framework compatible with any gate-based quantum simulator or hardware. We provide plugins for hardware providers including the Xanadu Cloud, Amazon Braket, and IBM Quantum, allowing PennyLane optimizations to be run on publicly accessible quantum devices. On the classical front, PennyLane interfaces with accelerated machine learning libraries such as TensorFlow, PyTorch, JAX, and Autograd. PennyLane can be used for the optimization of variational quantum eigensolvers, quantum approximate optimization, quantum machine learning models, and many other applications.

Note: Code available at https://github.com/XanaduAI/pennylane/ . Significant contributions to the code (new features, new plugins, etc.) will be recognized by the opportunity to be a co-author on this paper

PennyLane v0.38

- More stable and backwards compatible compared to Qiskit
- Has no own quantum machines and needs to make people sure that they can run on IBM machines and even use Pennylane with Qiskit: https://pennylane.ai/qml/demos/ibm_pennylane/, https://docs.pennylane.ai/projects/qiskit/en/latest/

PennyLane is a cross-platform Python library for quantum machine learning, automatic differentiation, and optimization of hybrid quantum-classical computations.

Qiskit is an open-source framework for quantum computing.

Using PennyLane with IBM's quantum devices and Qiskit

Clara Ferreira Cores   Kaur Kristjuhan   Mark Nicholas Jones

Published June 20, 2023. Last updated June 20, 2023.

Warning
This demo currently does not work as the Qiskit Runtime VQE program has been retired.

PennyLane: good to know

- Main channel of support: https://discuss.pennylane.ai/
- Has tutorials with funny pictures and even codebooks - but it all is definitely not for lazy people
- Has good quantum chemistry
- Better integration with PyTorch and Tensorflow compared to Qiskit

Closer to practice: RSA Algorithm

Key Generation

Select p, q	p and q both prime; $p \neq q$
Calculate $n = p \times q$	
Calculate $\phi(n) = (p-1)(q-1)$	
Select integer e	$\gcd(\phi(n), e) = 1;\ 1 < e < \phi(n)$
Calculate d	$de \bmod \phi(n) = 1$
Public key	$KU = \{e, n\}$
Private key	$KR = \{d, n\}$

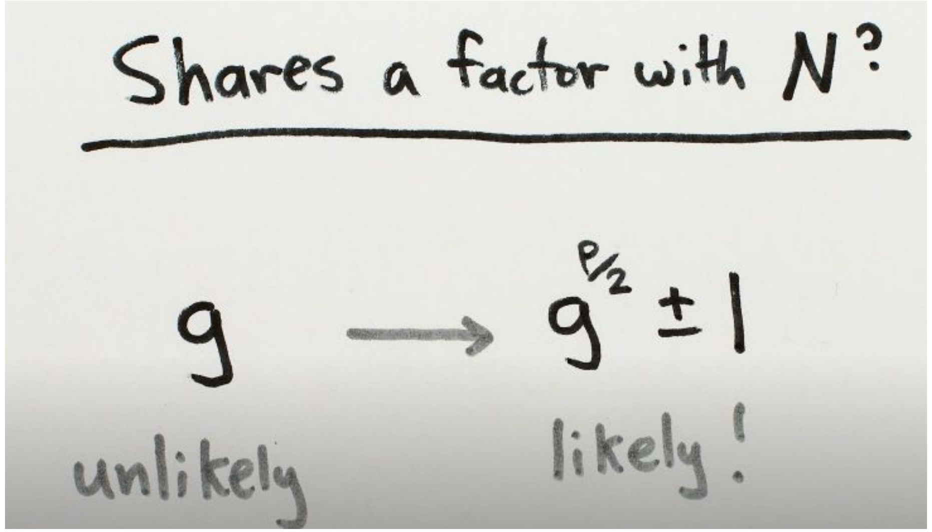
Encryption

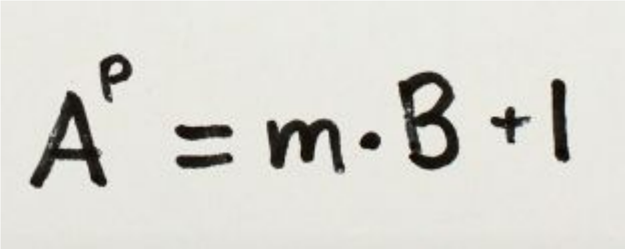
Plaintext:	$M < n$
Ciphertext:	$C = M^e \pmod{n}$

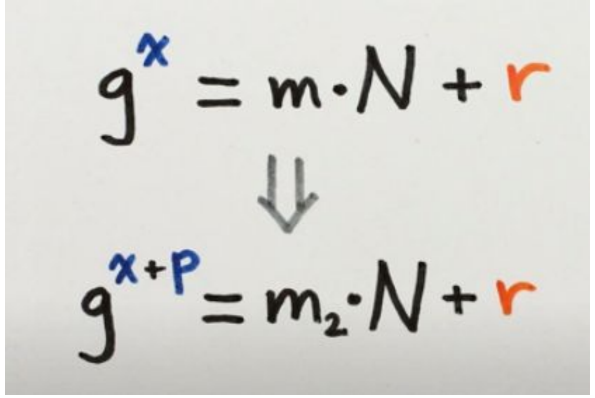
Decryption

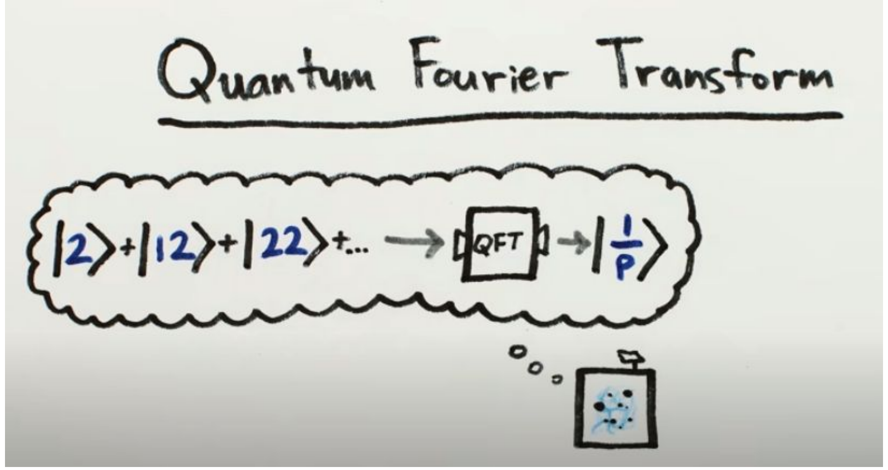
Plaintext:	C
Ciphertext:	$M = C^d \pmod{n}$

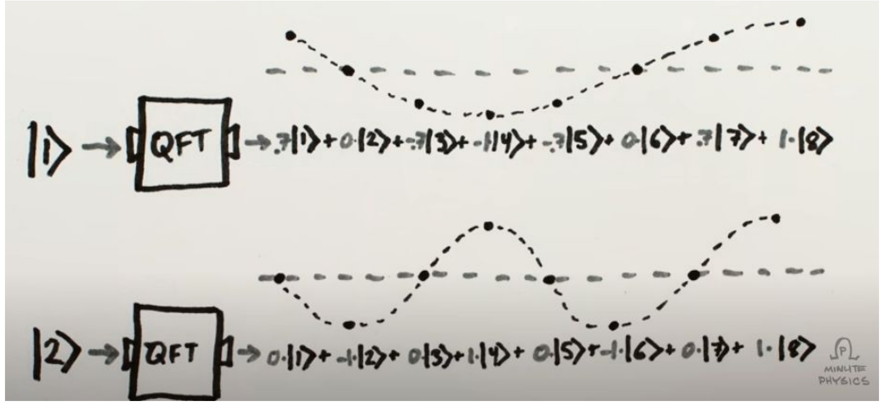
Shor's Algorithm







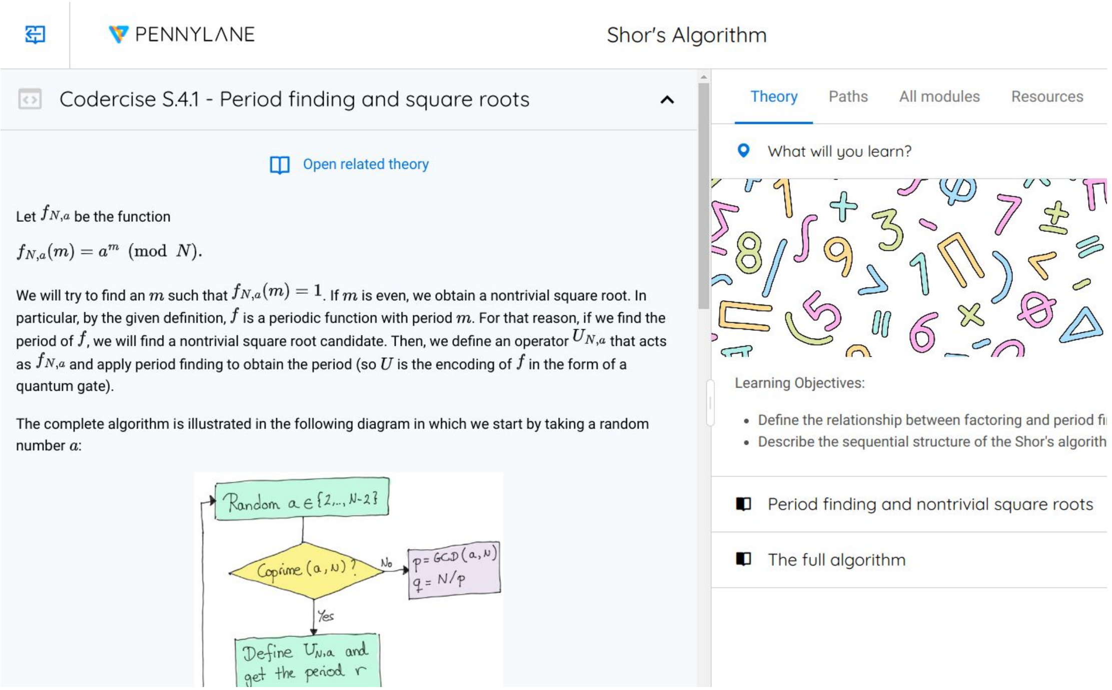




https://www.youtube.com/watch?v=lvTqbM5Dq4Q
https://www.youtube.com/watch?v=FRZQ-efABeQ

Shor's algorithm with Qiskit and PennyLane

- PennyLane: https://pennylane.ai/codebook/10-shors-algorithm/04-shors-algorithm/
- Qiskit: https://quantumcomputing.stackexchange.com/questions/38250/where-to-find-a-generic-implementation-of-shors-algorithm-with-qiskit



Financial aspect: Black Scholes Model

$$C = SN(d_1) - Ke^{-rt}N(d_2)$$

where:

$$d_1 = \frac{ln\frac{S}{K} + (r + \frac{\sigma_v^2}{2})t}{\sigma_s\sqrt{t}}$$

and

$$d_2 = d_1 - \sigma_s\sqrt{t}$$

and where:

C = Call option price

S = Current stock (or other underlying) price

K = Strike price

r = Risk-free interest rate

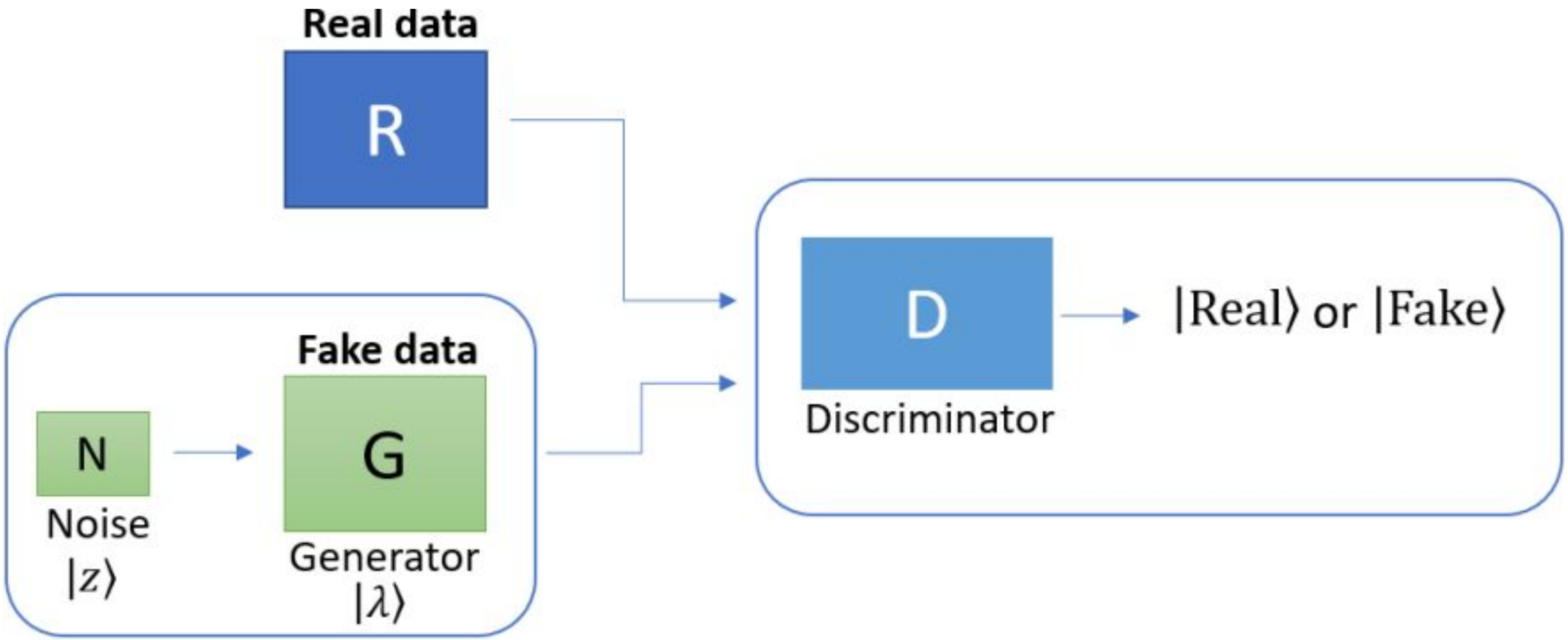
t = Time to maturity

N = A normal distribution

- Various limitations exist in the formula, including assuming a constant risk-free rate over time, a constant volatility over time, and stocks not paying dividends, to name a few. Despite these setbacks, bankers have adapted the formula to help accurately price options over time using partial derivatives

https://www.investopedia.com/terms/b/blackscholes.asp

Financial aspect: qGANs for option pricing



https://medium.com/geekculture/using-quantum-computers-to-price-options-5bd92ab5fe5c

An Experimental Comparison of Qiskit and Pennylane for Hybrid Quantum-Classical Support, 12 June 2024

- Link

Francesc Rodríguez-Díaz, José Francisco Torres, David Gutiérrez-Avilés, Alicia Troncoso & Francisco Martínez-Álvarez

Part of the book series: Lecture Notes in Computer Science ((LNAI,volume 14640))

Included in the following conference series:
Conference of the Spanish Association for Artificial Intelligence

Abstract

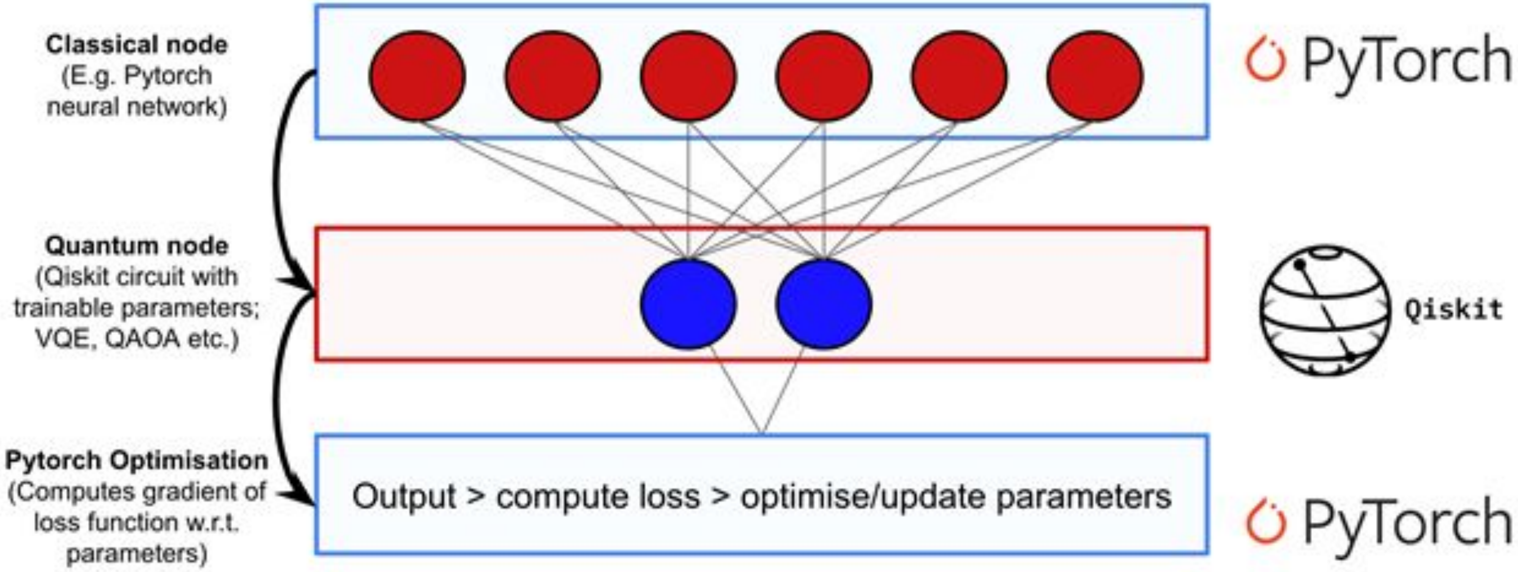
Quantum computing holds great promise for enhancing machine learning algorithms, particularly by integrating classical and quantum techniques. This study compares two prominent quantum development frameworks, Qiskit and Pennylane, focusing on their suitability for hybrid quantum-classical support vector machines with quantum kernels. Our analysis reveals that Qiskit requires less theoretical information to be used, while Pennylane demonstrates superior performance in terms of execution time. Although both frameworks exhibit variances, our experiments reveal that Qiskit consistently yields

Quantum Machine Learning Challenges

- **Loading data** from classical format to quantum **takes time**
- **Number of qubits is still not enough** for training models like quantum Chat-GPT and applied quantum chemistry
- Cost of quantum machines is ~**1.6$/sec**

Quantum Machine Learning Challenges

- That's why researchers mainly use hybrid classical-quantum
- It seems to be the same as with neural networks and GPU - we need to continue developing both algorithms and Python API, and wait when technology comes to the right point…



Quantum Machine Learning: what do we do?

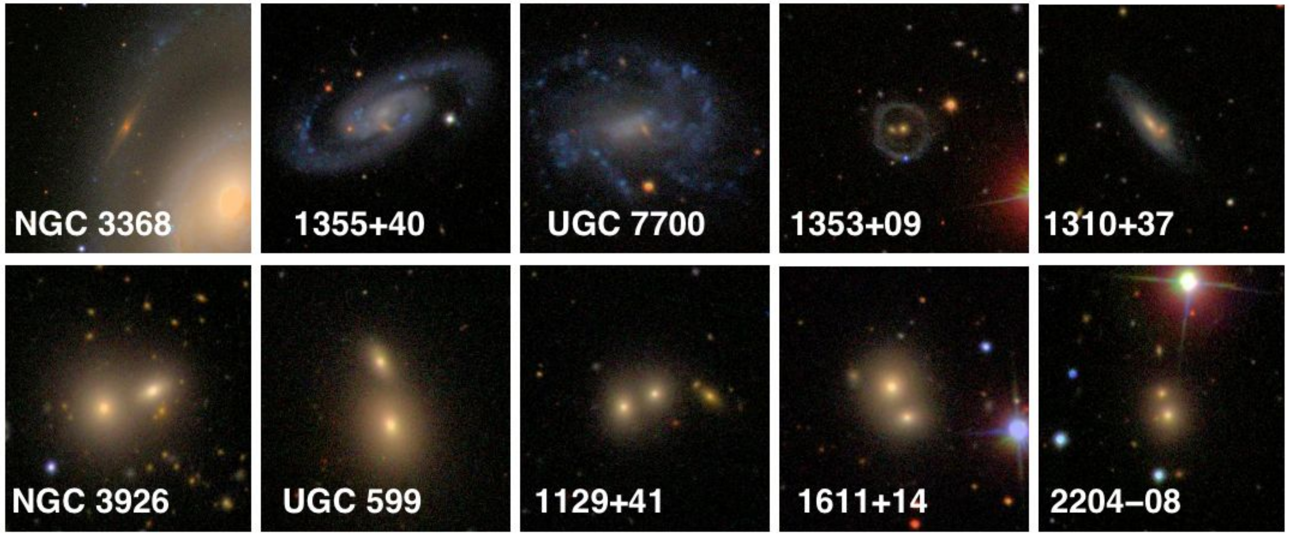
QardEst: Using Quantum Machine Learning for Cardinality Estimation of Join Queries

Authors: Florian Kittelmann, Pavel Sulimov, Kurt Stockinger   Authors Info & Claims

Q-Data '24: Proceedings of the 1st Workshop on Quantum Computing and Quantum-Inspired Technology for Data-Intensive Systems and Applications
Pages 2 - 13 • https://doi.org/10.1145/3665225.3665444

Published: 29 June 2024 Publication History

Check for updates



Quantum Computing: hottest news

QuEra Computing Announces Investment From Google Quantum AI

Insider Brief

- QuEra Computing announced a strategic investment from Google Quantum AI to assist in QuEra's efforts to develop scalable, fault-tolerant quantum computers, specifically using neutral atom technology.
- The investment builds on QuEra's collaboration with Harvard and MIT and is expected to accelerate the company's advancements in quantum error correction and other capabilities outlined in its strategic roadmap.
- This investment highlights Google's recognition of diverse quantum technologies, expanding its focus beyond superconducting qubits and positioning QuEra as a leader in neutral-atom-based quantum computing solutions for industries like materials science, pharmaceuticals, and finance.

2 days ago

Chinese Researchers Claim Breakthrough in Cracking RSA Encryption Using Quantum Computing

Claudio Gallo · Follow
4 min read · 7 hours ago

55

In what is seen as a severe prelude to malicious cybersecurity and quantum computing activities, researchers from Shanghai University in China reported that they successfully hacked RSA encryption using quantum computers. A new breakthrough, in concert with D-Wave's Advantage quantum computer, brings the future security of today's robust encryption methods into question. The experts also maintained that this immediate

4 days ago

Thank you (or not, with probability 0.5)