QUANTUM MACHINE LEARNING

Challenges and Opportunities

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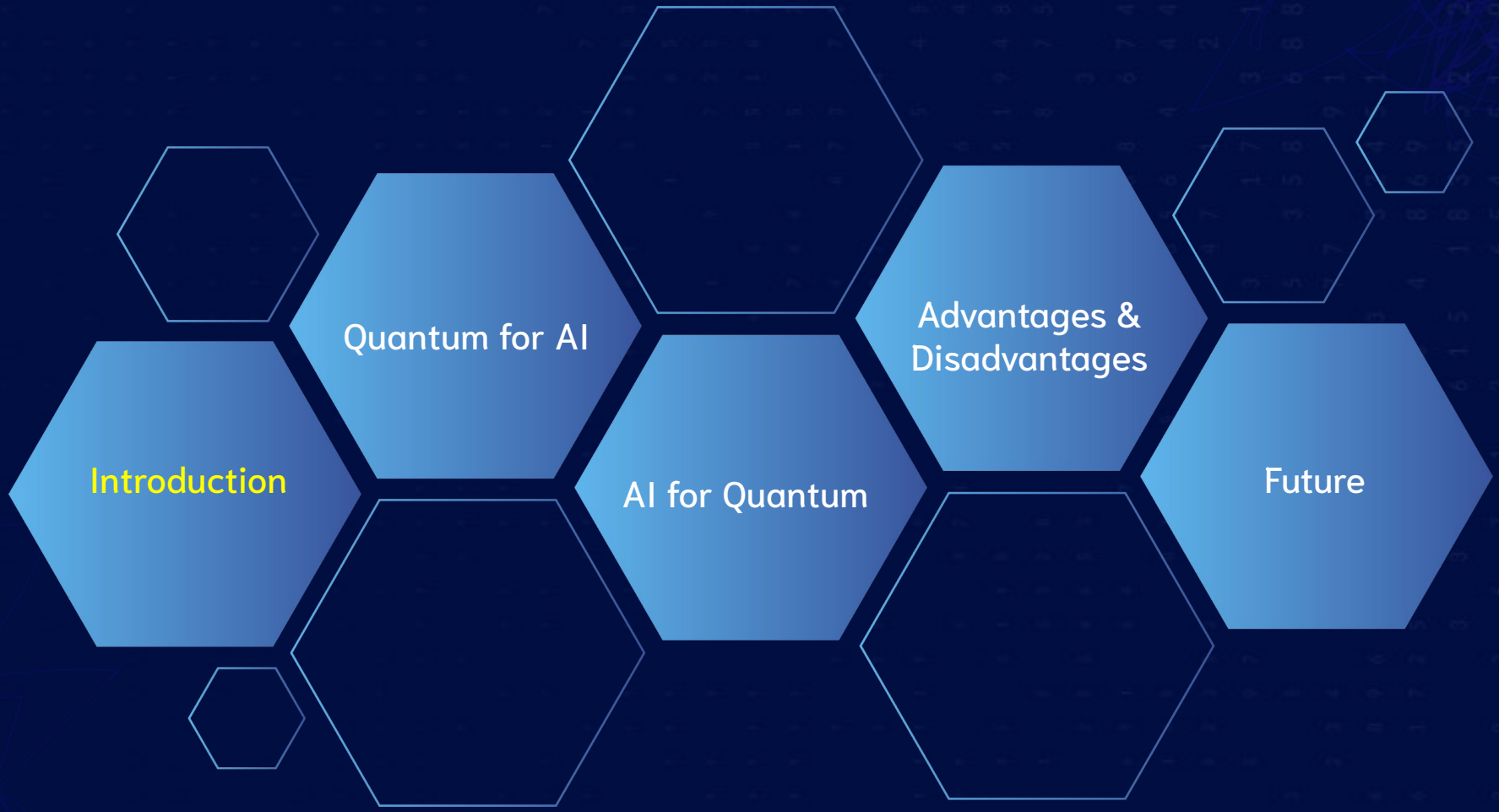


QUANTUM COMPUTING AT A GLANCE

2000 Yuri Manin & Richard Feynman forces the thought of Quantum Computing

2012 Shor's algorithm to discover prime components

2014 Grover search algorithm made huge interest in Quantum

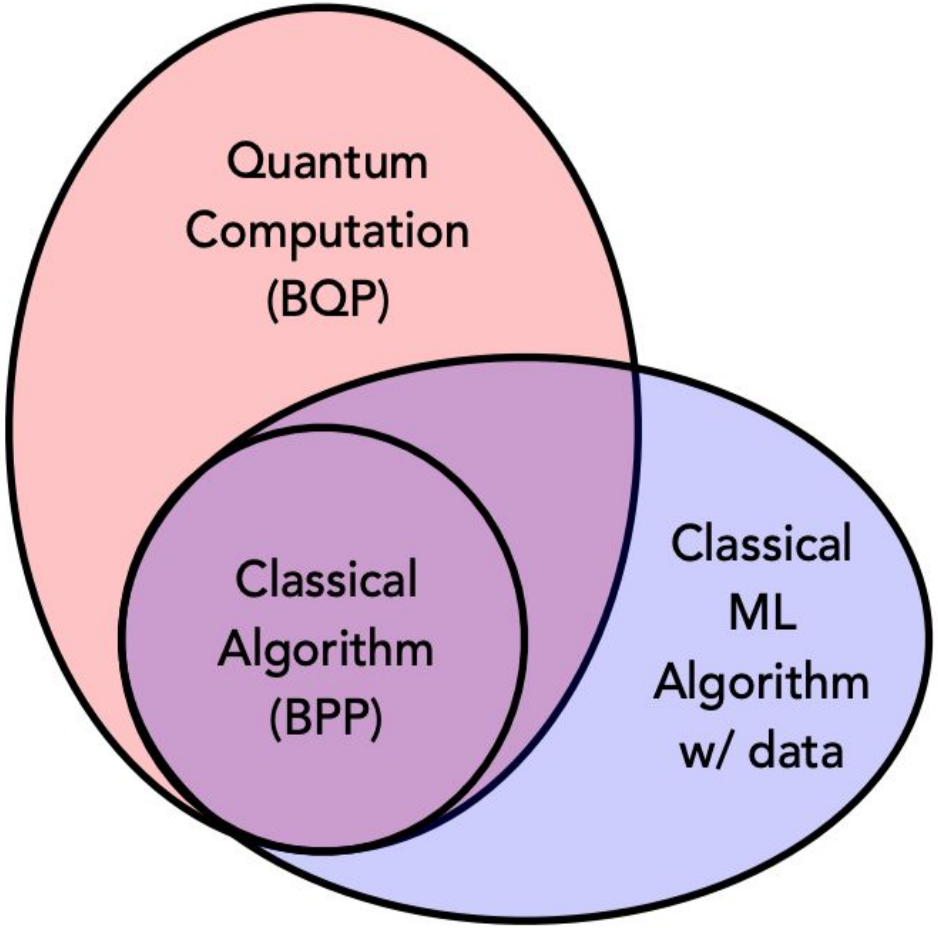
2016 First operating two-qubit quantum Computer model

2018 D-Wave launched first quantum computer officially

2020 IBM released a quantum platform for application development

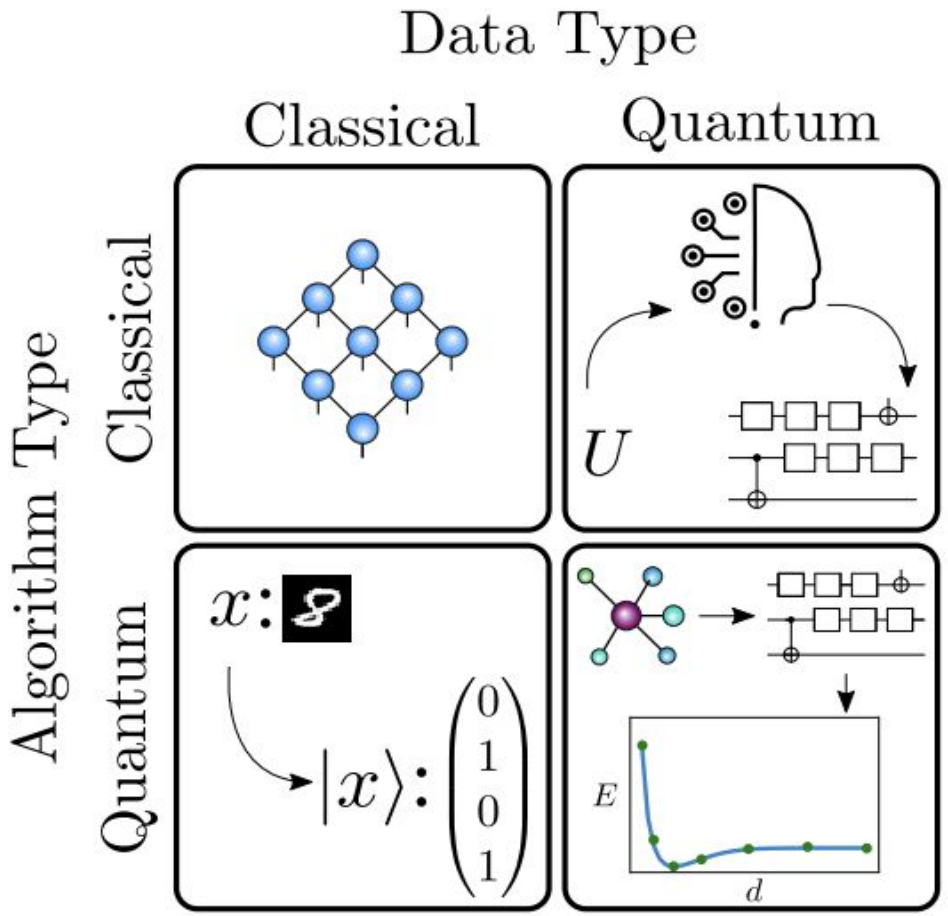
WHAT IS QUANTUM MACHINE LEARNING ?

Quantum Computing + Machine Learning = ?



source:https://www.marktechpost.com/2020/11/24/exploring-the-power-of-data-in-quantum-machine-learning/

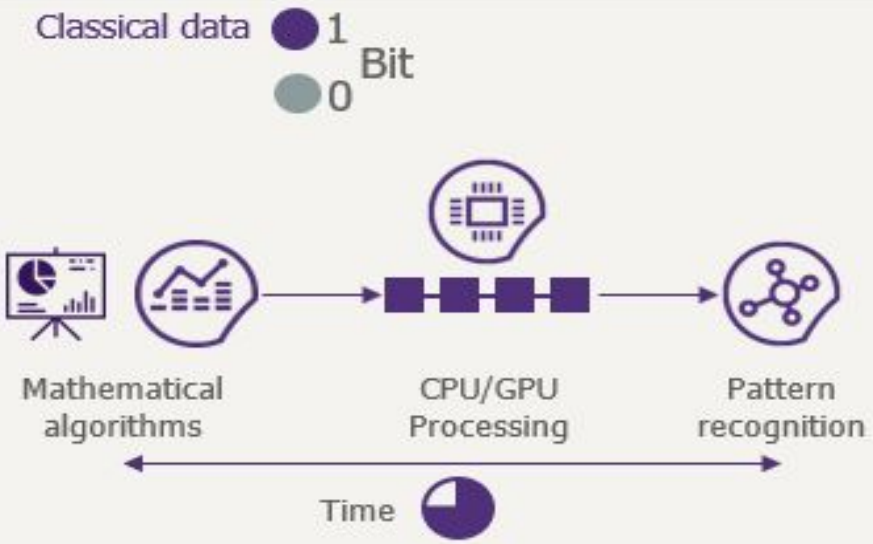
Data type + Algorithm Type = ?

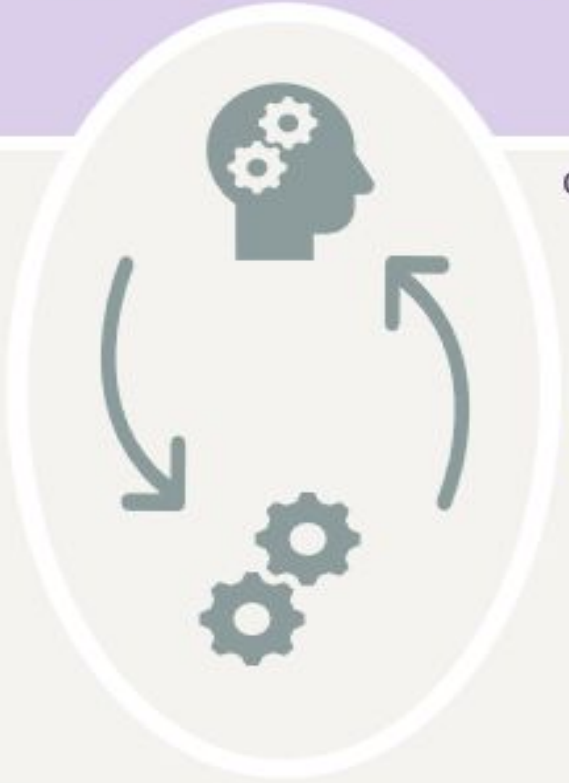


source: https://arxiv.org/abs/2303.09491

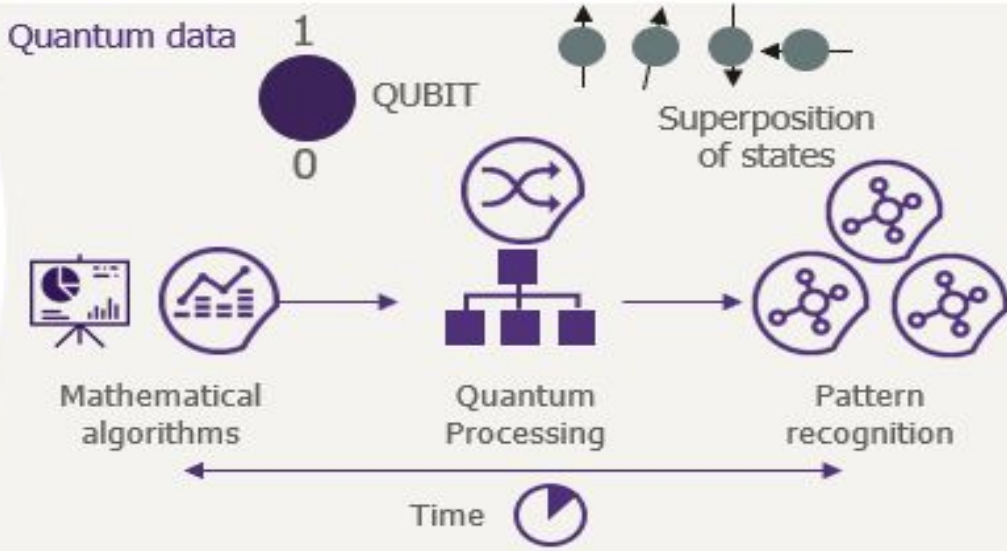
Machine Learning

Classical Machine Learning - CML

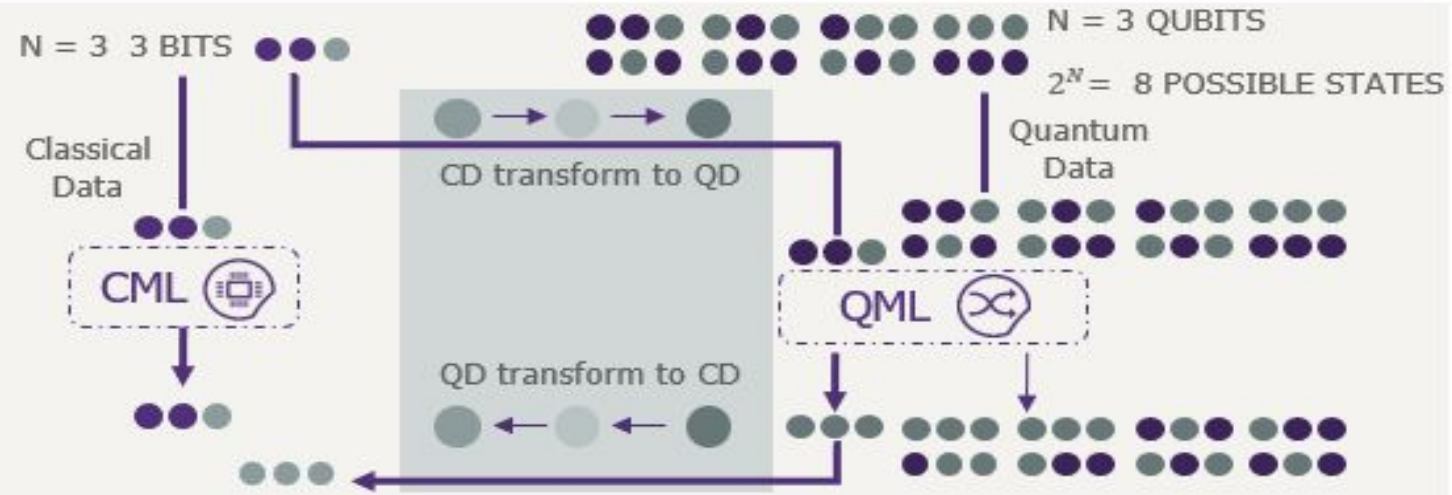




Quantum Machine Learning - QML



Processing methods



Applications

https://thequantuminsider.com/2020/05/28/quantum-machine-learning-is-the-next-big-thing/

QUANTUM MACHINE LEARNING TOOLS

Pennylane

Pennylane is an open-source quantum framework that provides tools for creating, editing, and running quantum circuits focusing on quantum machine learning and optimization.

Qiskit

Developed by IBM, Qiskit is an open-source quantum computing framework that allows you to create and run quantum circuits, access quantum hardware, and develop quantum algorithms.

Quantum simulators

Various quantum simulators are available for simulating quantum circuits on classical hardware. These include the simulators included in Qiskit and Cirq, as standalone tools like the Quantum Development Kit from Microsoft.

APPLICATIONS OF QUANTUM MACHINE LEARNING

Artificial Intelligence

Environmental Impact

Traffic and Transportation

Cryptography and Security

Optimization Problems

QUANTUM MACHINE LEARNING IN INDUSTRY

Quantum machine learning has the potential to revolutionize various industries by offering the capability to solve complex problems much faster than classical computers.

FINANCE AND RISK ANALYSIS

Optimizes portfolios pricing derivatives, enabling risk assessment.

SUPPLY CHAIN AND LOGISTICS

Streamline route planning, inventory management, and demand forecasting for cost savings.

PHARMACEUTICALS AND DRUG DISCOVERY

Accelerate drug discovery by modeling molecular interactions..

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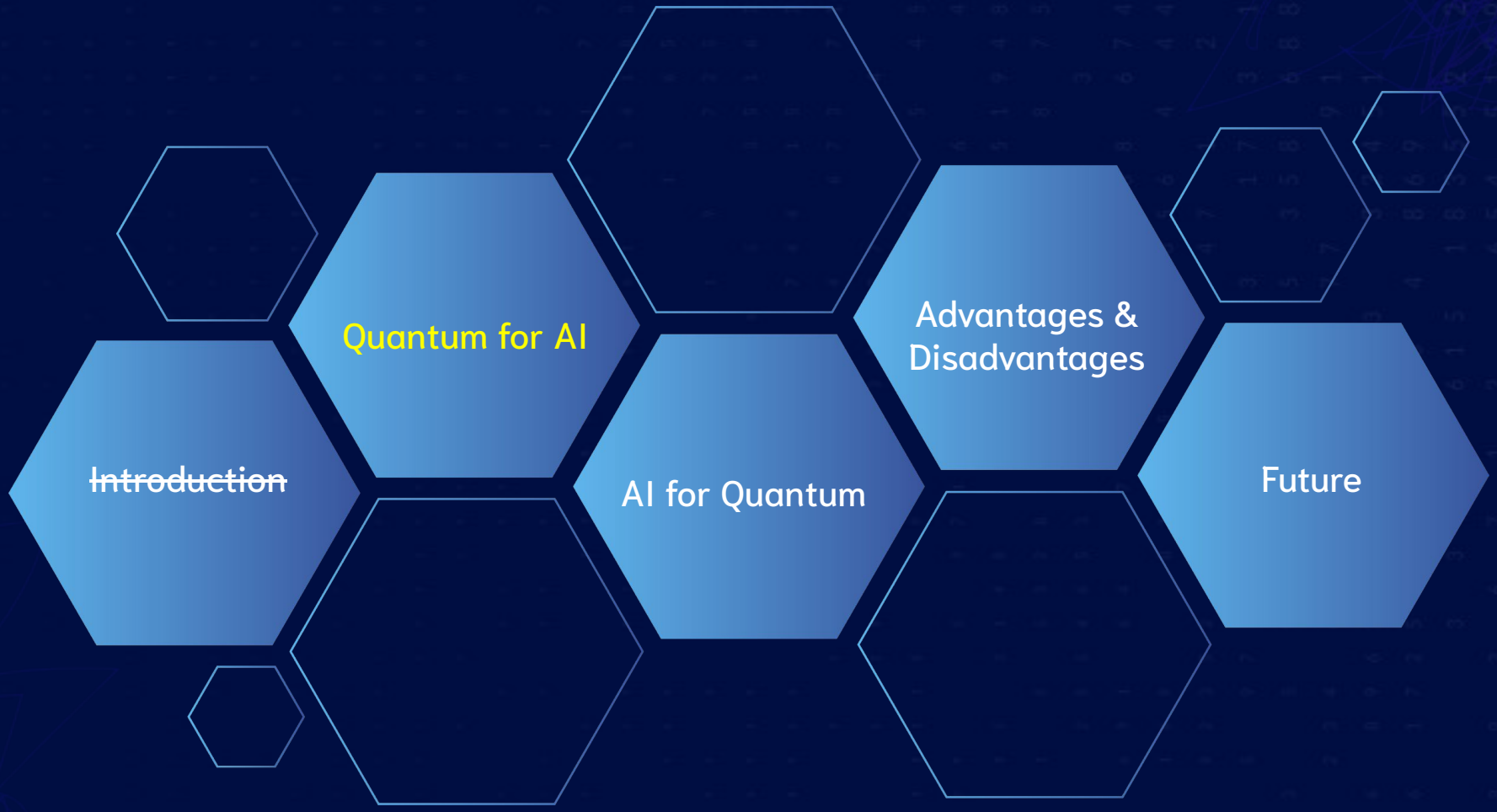
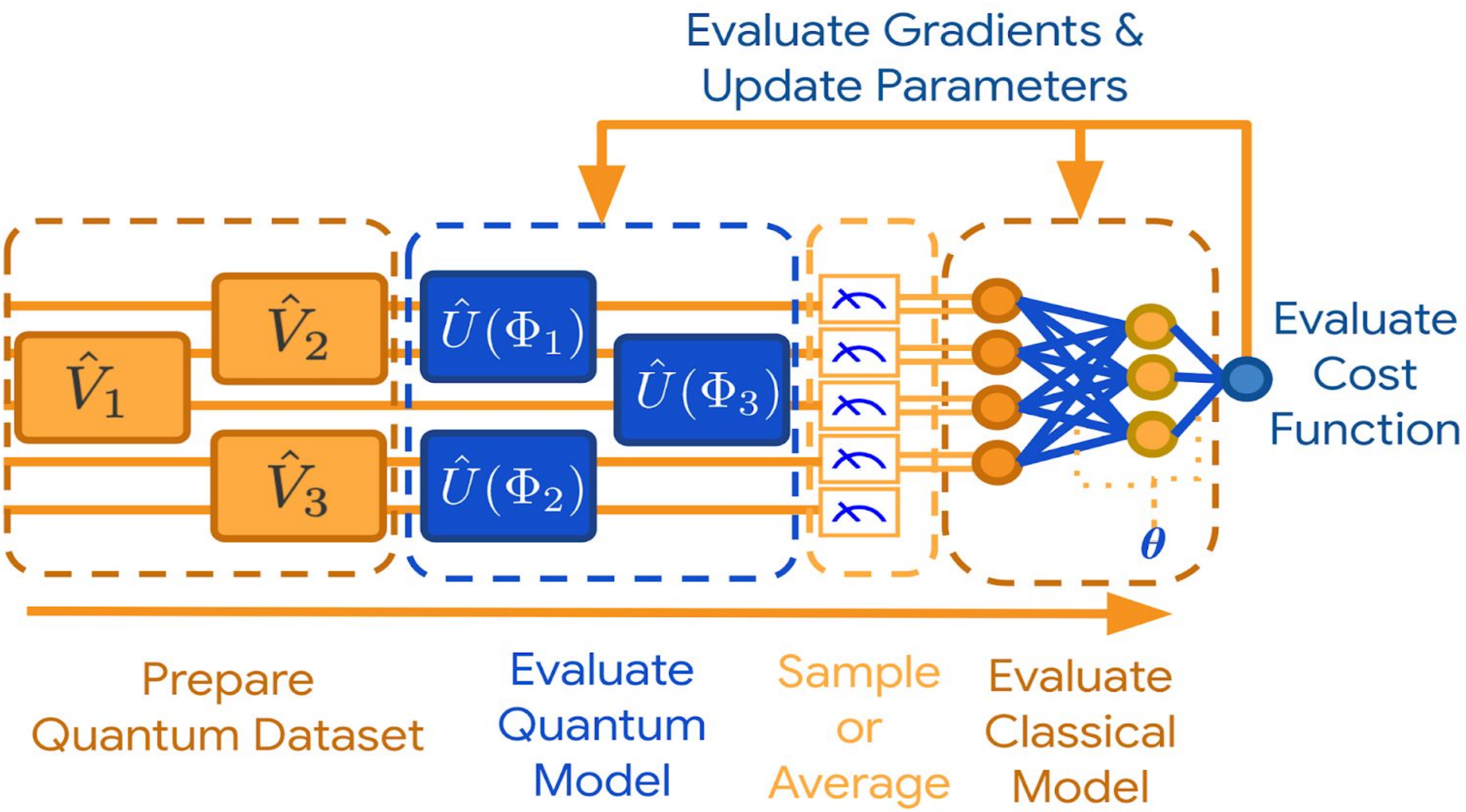




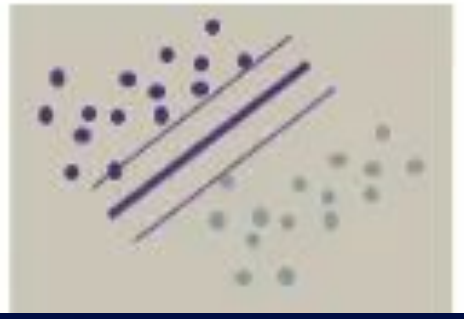
source: https://research.google/blog/announcing-tensorflow-quantum-an-open-source-library-for-quantum-machine-learning/?ref=blog.paperspace.com

Quantum Clustering finding

When the data is represented in a very large dimension space, it is very difficult to perform the clusetring with a classical computer. The use of quantum computers is a very good solution.

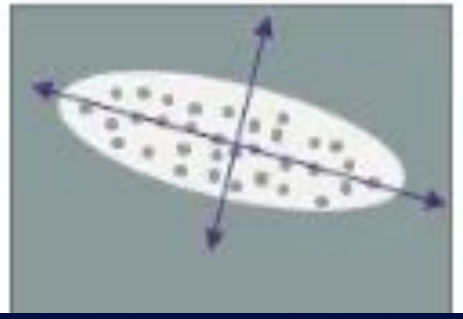
Quantum Support Vector Machine

Finding the hyperplane that separates many data points that are represented in a high dimensional space is so difficult on a classical computer. on a quantum computer, it can be solved extremely efficiently.



Quantum PCA

The goal of this algorithm is to find the proper axes along which to group this data. This is something that takes $O(N^2)$ on a classical computer. But in quantum version you can do it exponentially faster.



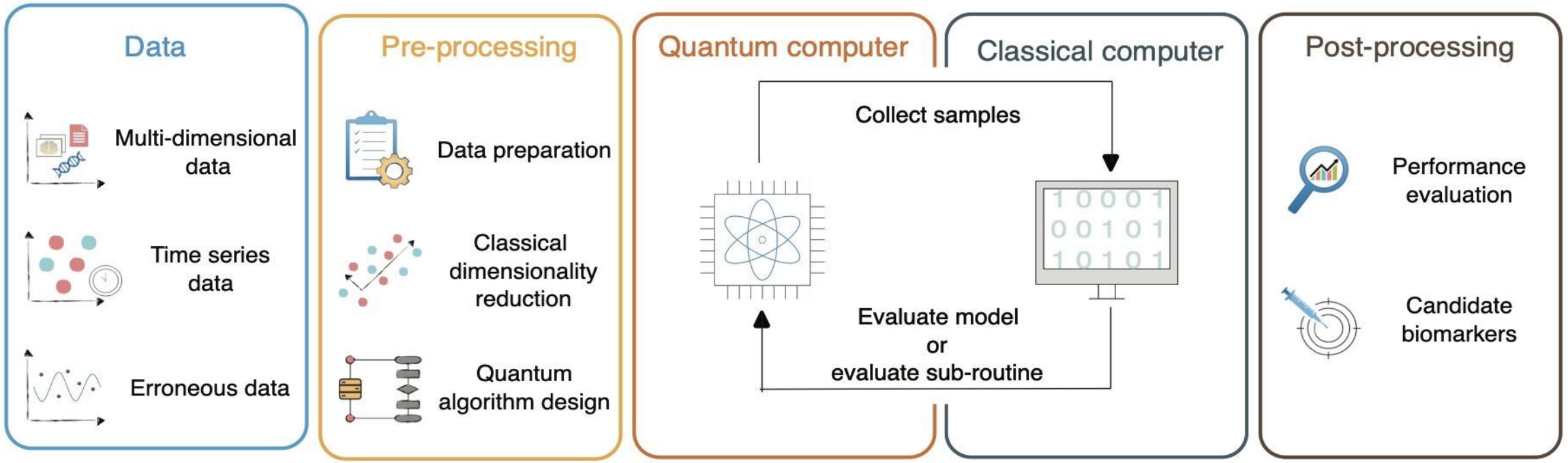
Feature topology

This is a method for finding the topological features of data. This problem can be mapped to a problem of finding the eigenvectors and eigenvalues of some huge, high-dimensional matrix.

Quantum Deep Learning

Exciting breakthroughs may soon bring real quantum neural networks, specifically deep learning neural networks, to reality. Many research papers have shown remarkable results in quantum deep learning

source: https://medium.com/student-technical-community-vit-vellore/machine-learning-the-quantum-way-f05c73e1ced7



Modality	Pre-processing	Quantum algorithms	Classical algorithms	Use case application
Electronic health records	Definition of relevant cohorts, data quality analysis, imputation	QML, QRNNs, QReservoir , QNLP, linear equation solving with quantum algorithms	Deep learning, ML and statistical learning Small/missing data, undetermined system, data quality, multi-modality, generalizability	Clinical note processing, population stratification, drug/patient response
Omics	Noise removal (intra- and inter-omics variability), size reduction, normalization, imputation	QML, QK-means, QBMs, QVAE, Quantum least squares, QGNNs, VQE, QAOA, linear equation solving with quantum algorithms	Deep learning, ML and statistical learning Small/missing data, multi-modality, exponential scaling of resources, undetermined system	GWAS, population stratification, gene regulatory network, drug/patient response, disease subtyping and progression
Medical images	Background removal, denoising, resampling, registration, intensity normalization	QML, QGAN, QVAE, QTDA	Deep learning, ML Data volume, labelling, processing power	Identification of region of interest, disease subtyping and progression

source: https://www.linkedin.com/posts/rajiv-k_new-preprint-on-potential-applications-activity-7271105163392618496-L_VT/

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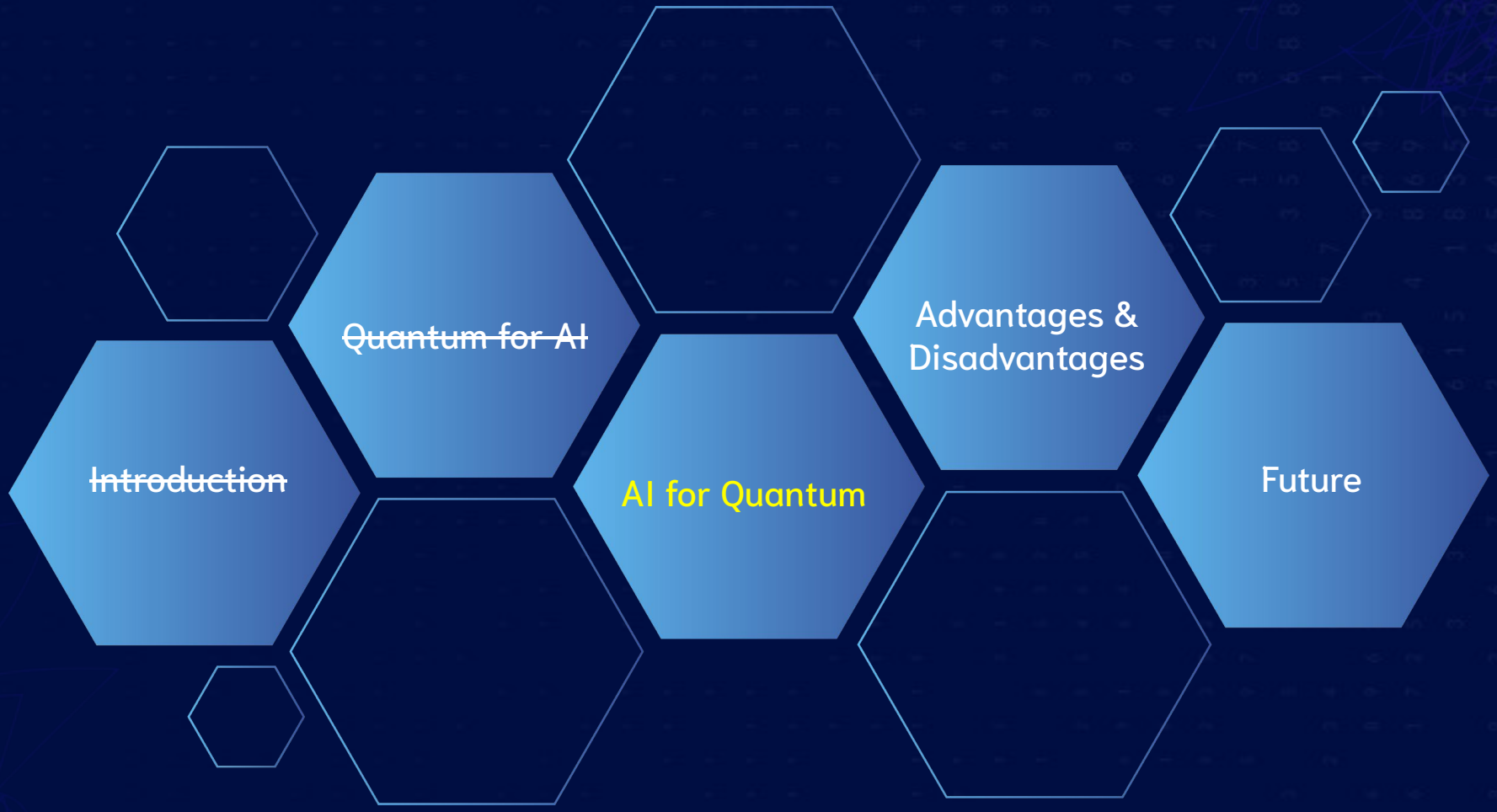
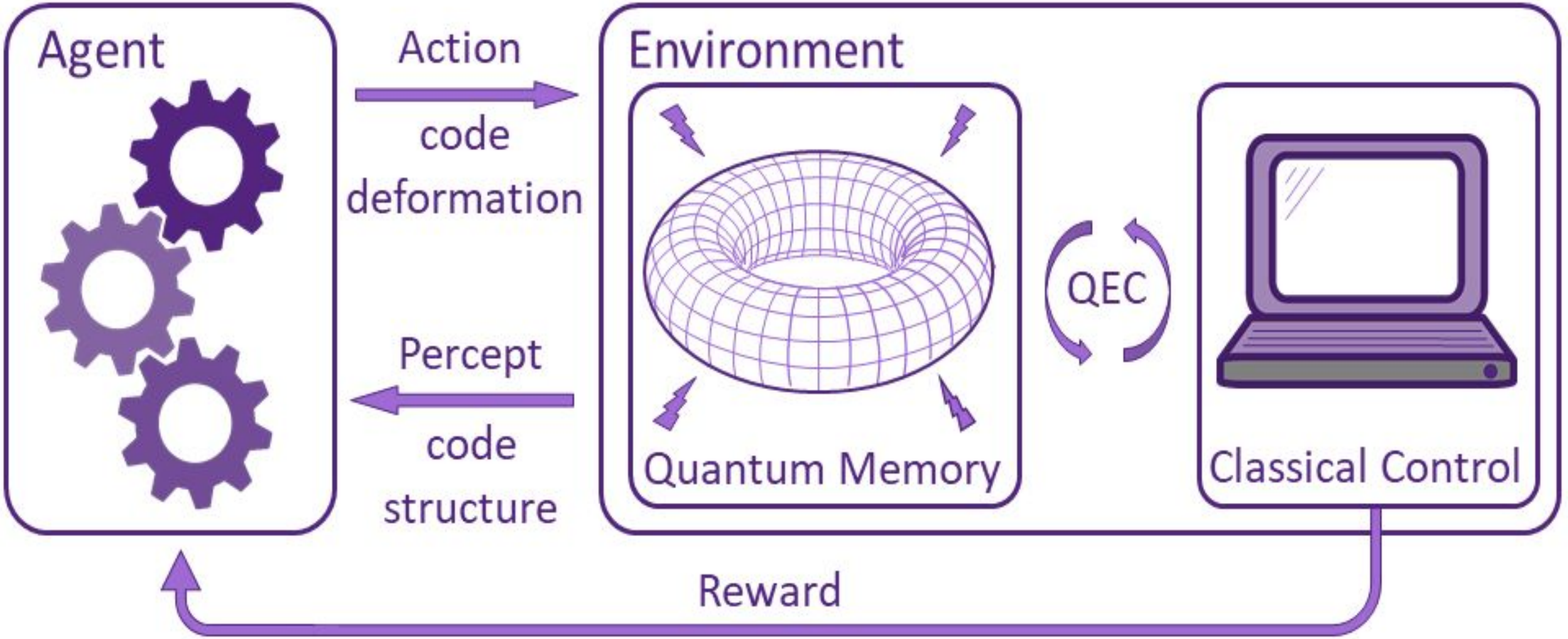
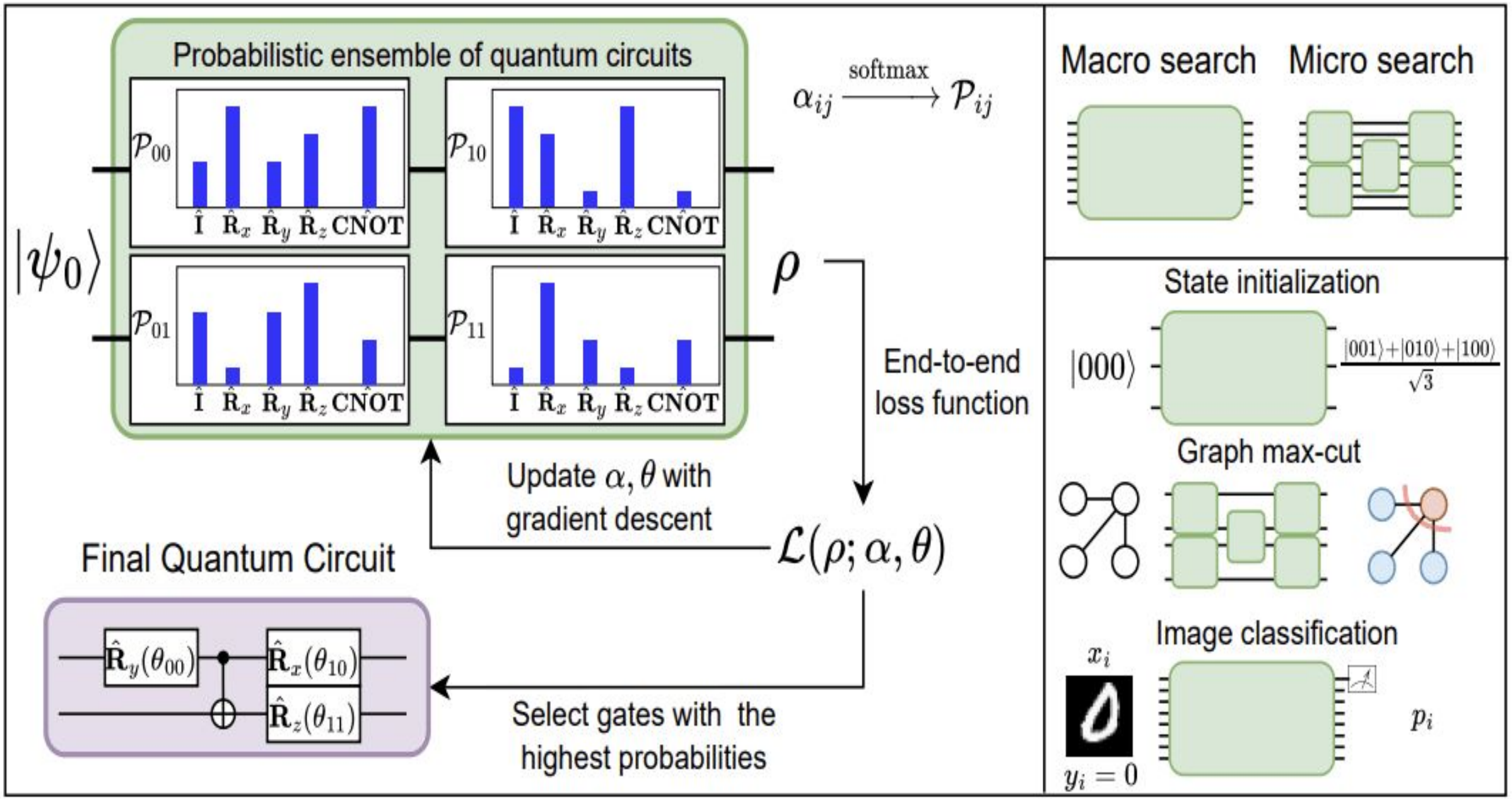




source: https://quantum-journal.org/papers/q-2019-12-16-215/ (QEC: Quantum Error Correction)



source: https://quantumzeitgeist.com/quantum-neural-networks-evolve-with-differentiable-architecture-search-for-improved-performance/

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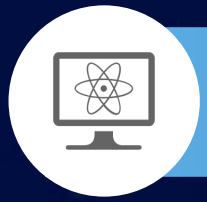
QUANTUM ML VS. CLASSICAL ML

ADVANTAGES

- Potential for speedups in high-dimensional problems.
- Naturally handles **quantum data** (e.g., quantum chemistry, material science).
- Can exploit **quantum parallelism** for certain optimization and sampling tasks.



DISADVANTAGES

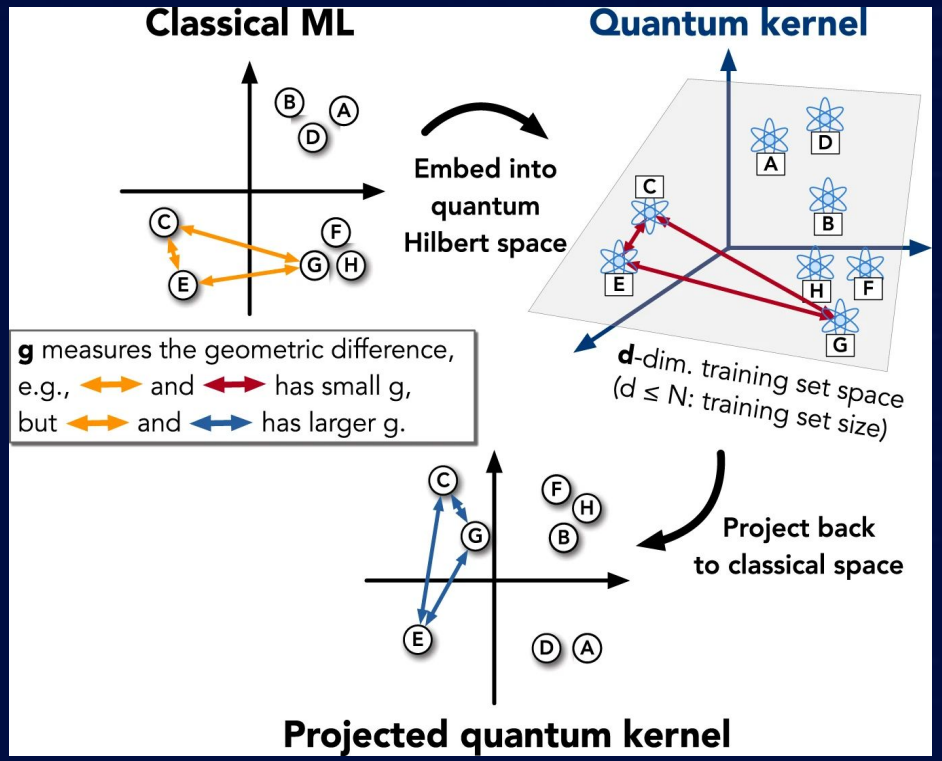
- **Hardware limitations** (low qubit counts, noise, short coherence times).
- **Data encoding bottleneck** — often nullifies theoretical speedups for classical data.
- Algorithms may give only *polynomial* speedups, not always exponential.
- Still an **active research area**; few real-world advantages demonstrated yet.

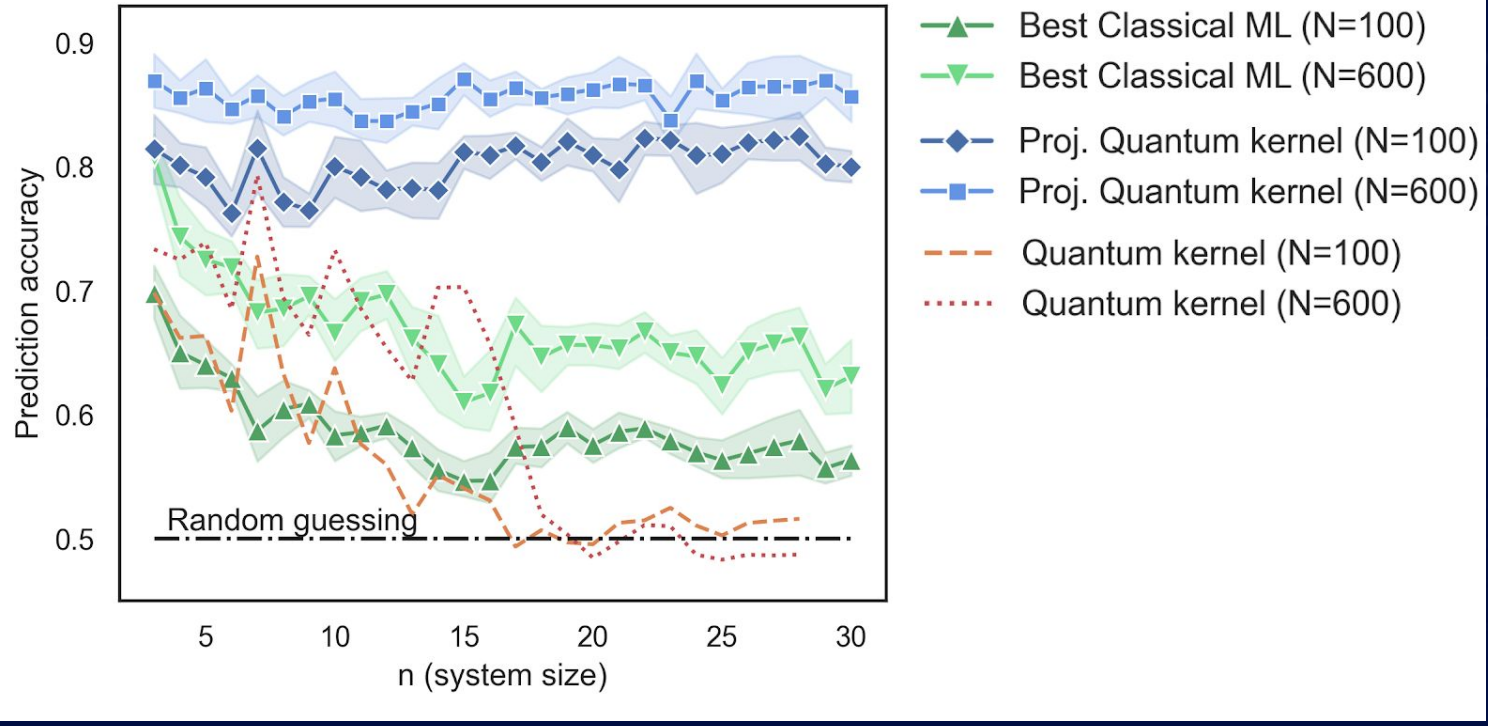
Article | Open access | Published: 11 May 2021

Power of data in quantum machine learning

Hsin-Yuan Huang, Michael Broughton, Masoud Mohseni, Ryan Babbush, Sergio Boixo, Hartmut Neven & Jarrod R. McClean

Nature Communications **12**, Article number: 2631 (2021) | Cite this article





PAPER • OPEN ACCESS

Qsun: an open-source platform towards practical quantum machine learning applications

Quoc Chuong Nguyen, Le Bin Ho, Lan Nguyen Tran and Hung Q Nguyen

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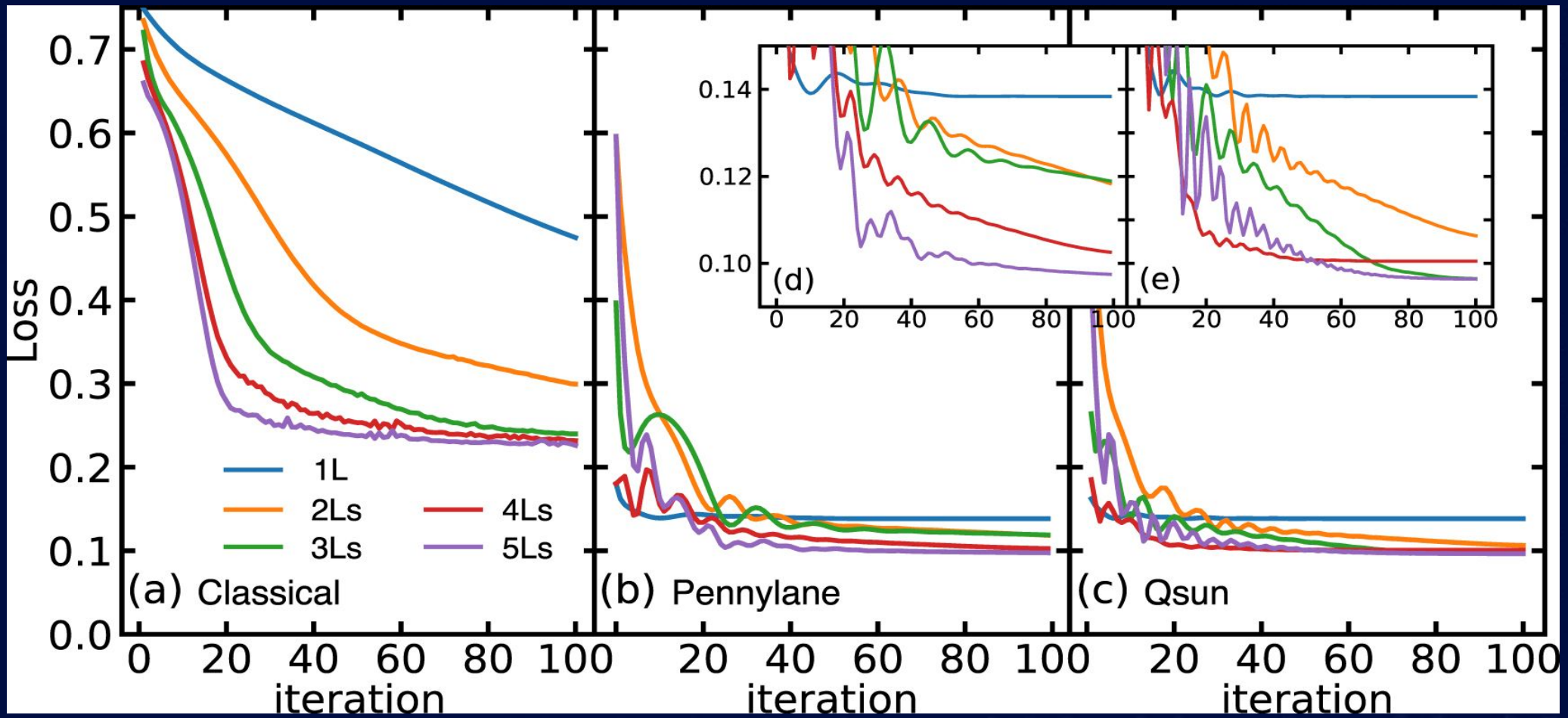

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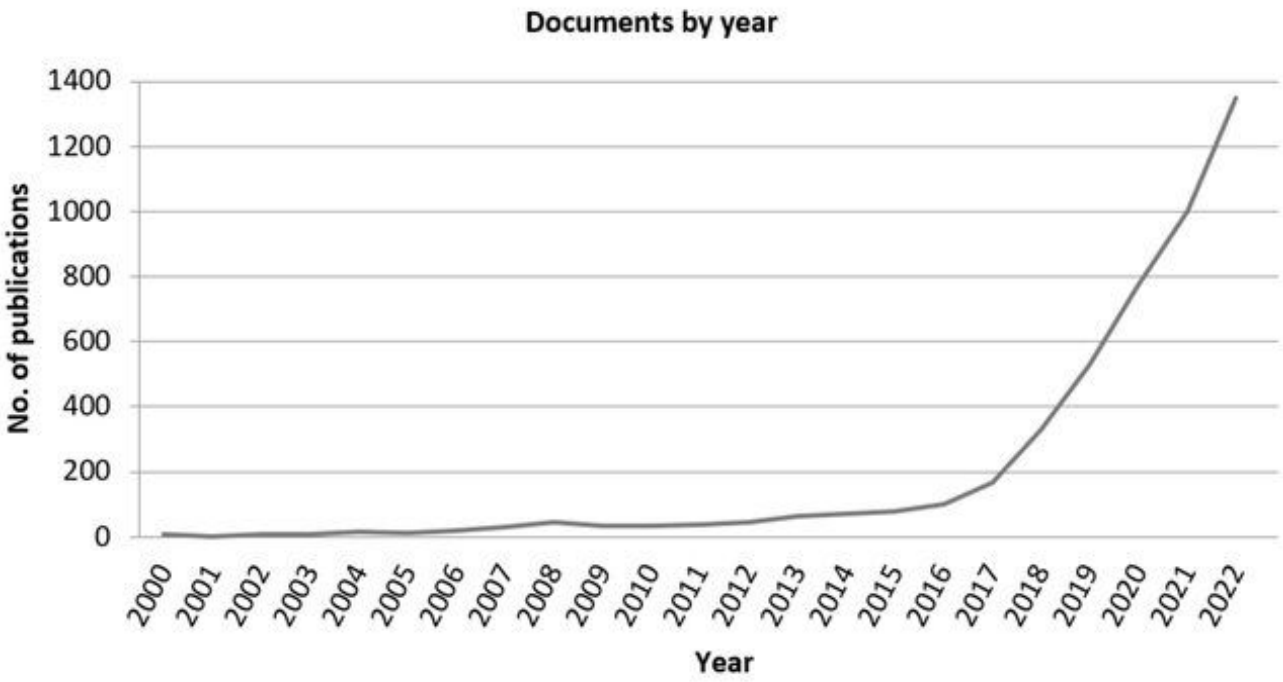
QUANTUM COMPUTERS IN DEVELOPMENT

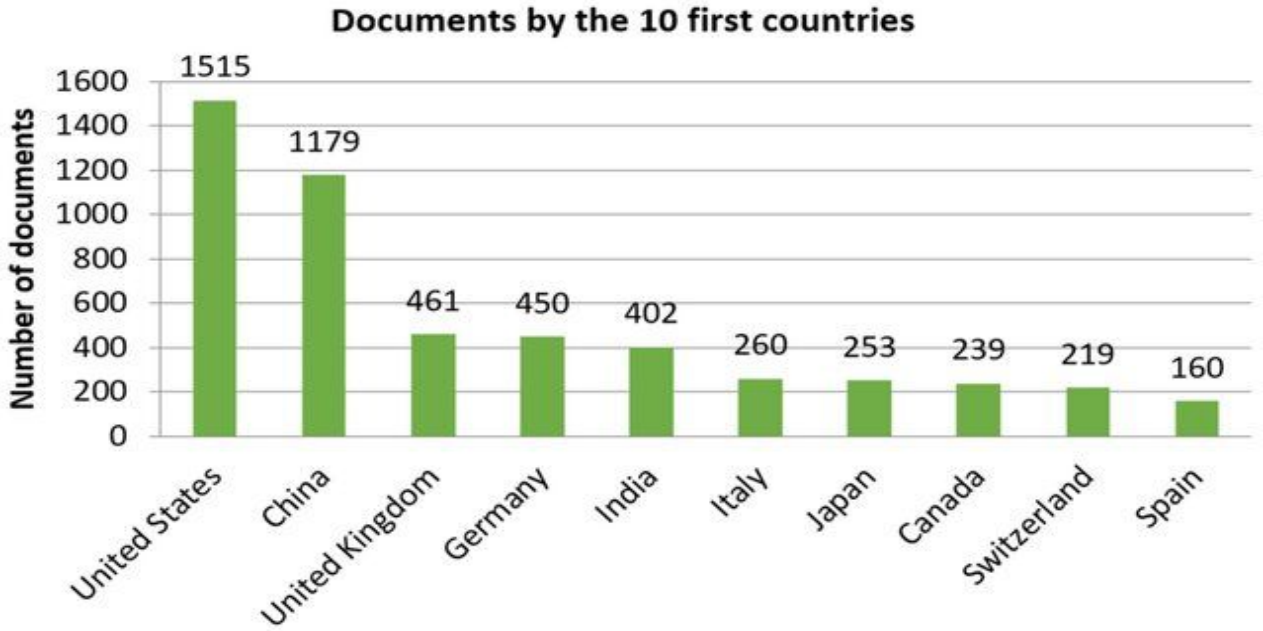
1. **GOOGLE** is spending billions of dollars to build its quantum computer by 2029. The company opened a campus in California called Google AI to help it meet this goal.

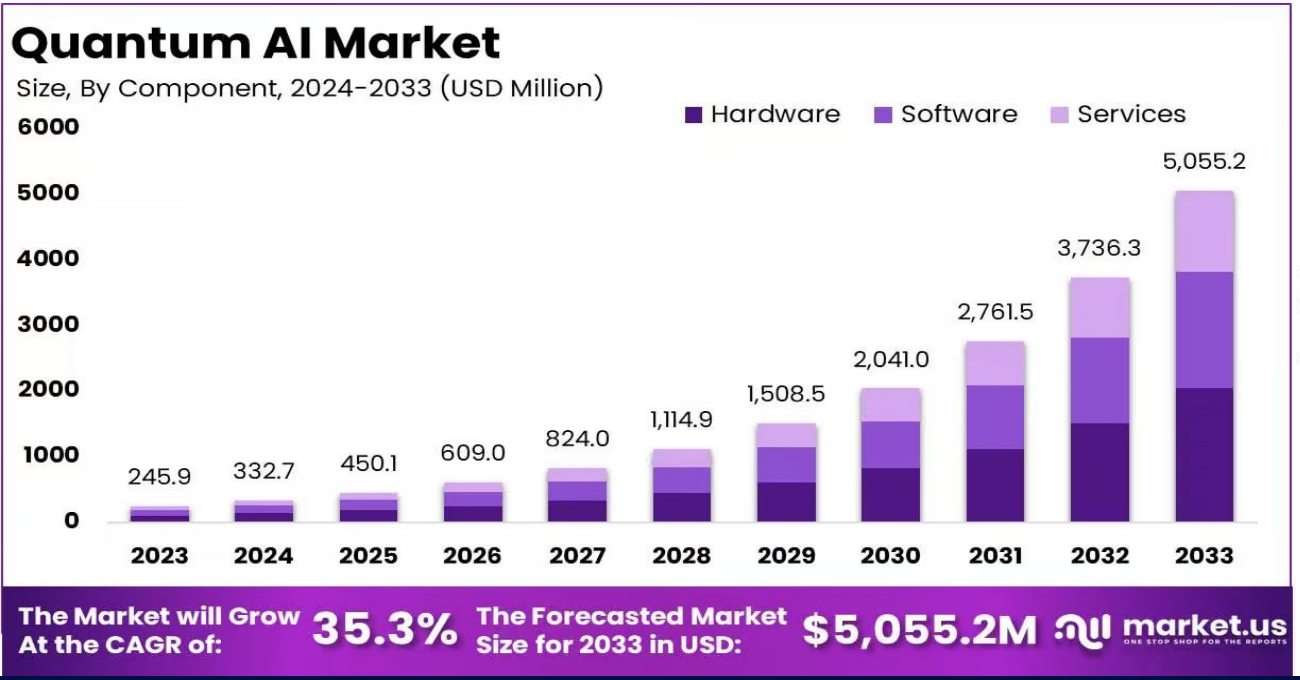
2. **IBM** plans to have a 1,000-qubit quantum computer in place by 2023. For now, IBM allows access to its machines for those research organizations.

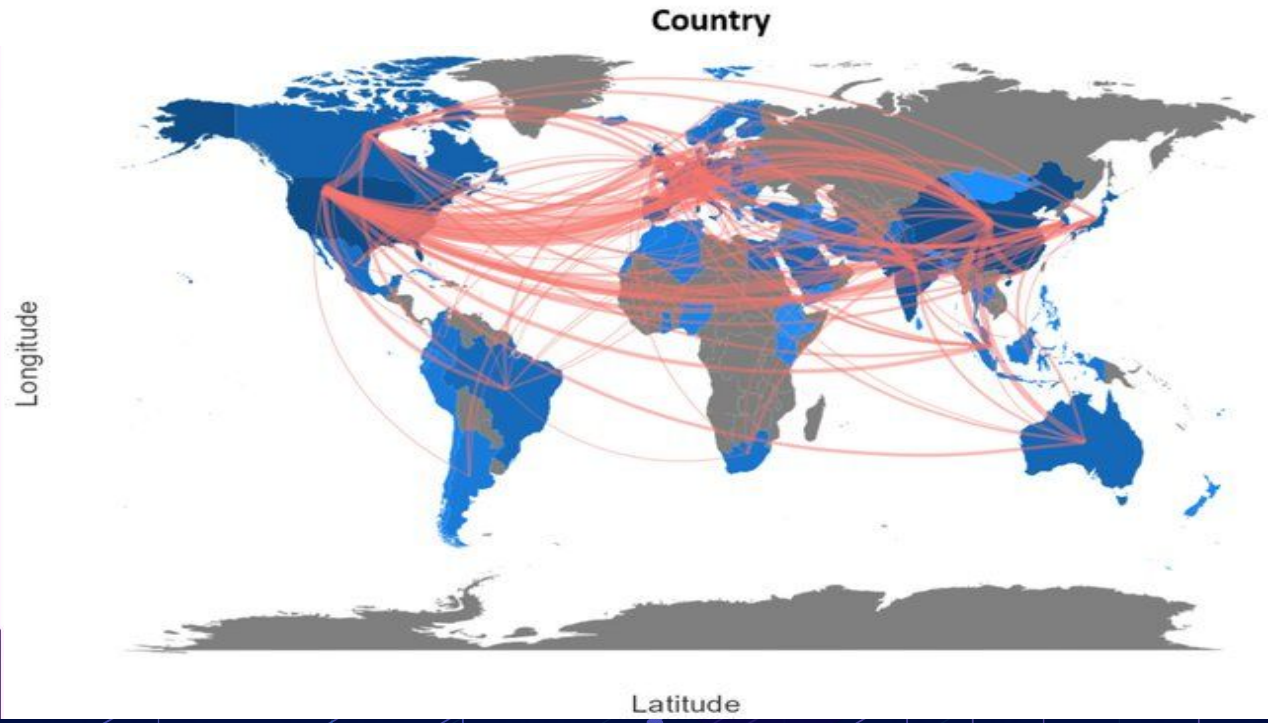
3. **MICROSOFT** offers companies access to quantum technology via the Azure Quantum platform.

4. **OTHERS** There's interest in quantum computing and its technology from financial services firms such as JPMorgan Chase and Visa.









https://market.us/report/quantum-ai-market/

https://https://www.mdpi.com/2079-9292/12/11/2379

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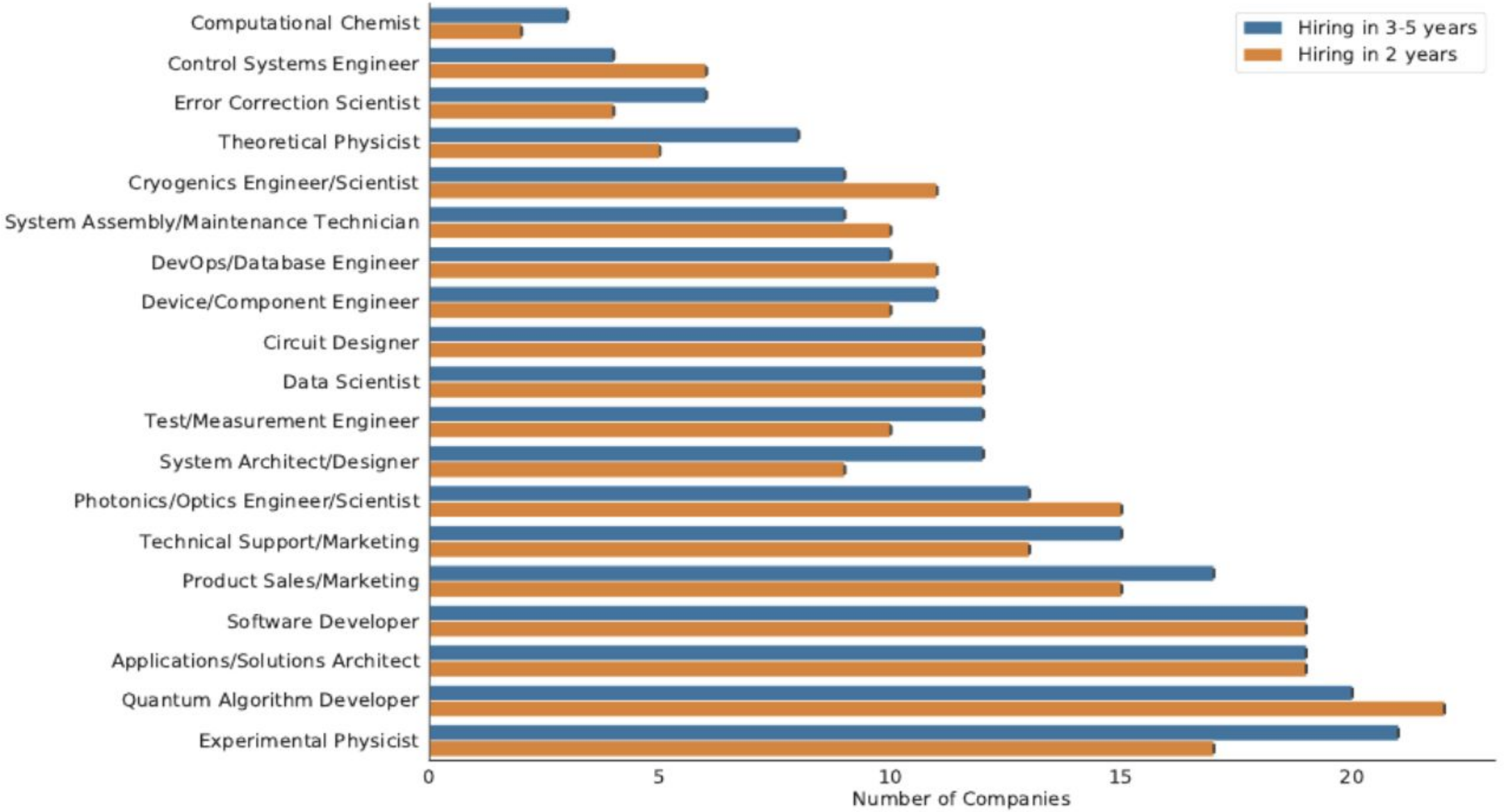

FIG. 1: The number of companies out of 57 (x-axis) that indicated they would hire a job type (y-axis) over the next 2 years (blue) or the next 3-5 years (orange). Note that the data are similar over the two time periods, as discussed in the text.

source: https://arxiv.org/abs/2109.03601

THANK YOU