Applied QML

Lecture 12: The quest for useful applications - Don't be afraid to fail

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Table des matières

Hype

They'll solve climate change, and make modern cryptography obsolete. They might revolutionize drug discovery, or make gene editing as easy as a simple cardiogram

"quantum computing will change life as we know it,"
"quantum computing will solve global warming,"
"Quantum computing will revolutionize science and industry,"

Quantum is faster than classical

Quantum does everything in parallel

All cryptographic schemes will be at risk

Quantum computing came from crashed UFO alien spacecraft

Conspiracy theory

Learning quantum computing requires a PhD in physics.

https://quantumzeitgeist.com/the-quantum-hype-machine/

https://www.politico.com/newsletters/digital-future-daily/2023/10/03/checking-in-on-the-quantum-hype-00119742

Reality

Peter Wittek

"QML is not here to replace what we already have," Peter says. "It is good at certain learning tasks where digital computers have been struggling to keep up with the computational requirements. There is absolutely no point in unleashing a $15M quantum computer on a learning task that you can solve on a $1000 GPU. Keep training your deep learning networks on your GPU cluster and do tasks on a quantum computers that you cannot solve by deep learning.

"For the next five, six, seven or even ten years, we are going to have noisy quantum systems that have a limited scale. The good news is that these imperfect quantum computers offer certain algorithmic building blocks that are useful in creating learning algorithms. I believe that is the main reason we should be looking at QML in the first place. I expect that hardware will be on the scale to give you a boost in certain applications in about three to five years."

https://s3.amazonaws.com/external_clips/3667813/Quantum_machine_learning_3.pdf?1610373485

Quantum Inspired

Quantum-inspired Machine Learning: the integration of quantum computing concepts to enhance traditional machine learning algorithms, without requiring actual quantum computation

Definition 1:
Quantum-Inspired Machine Learning (QiML) refers to machine learning algorithms that draw inspiration from principles of quantum mechanics or quantum computing constructs, but do not necessitate quantum processing and can be executed on classical hardware.

Quantum Inspired

Méthodes actuelles

- Déquantisation
  - Ewin Tang, 2019

  → Permet de déterminer l'efficacité de l'approche quantique

- Tensor Networks
- VQA
- Autres

Quantum Inspired

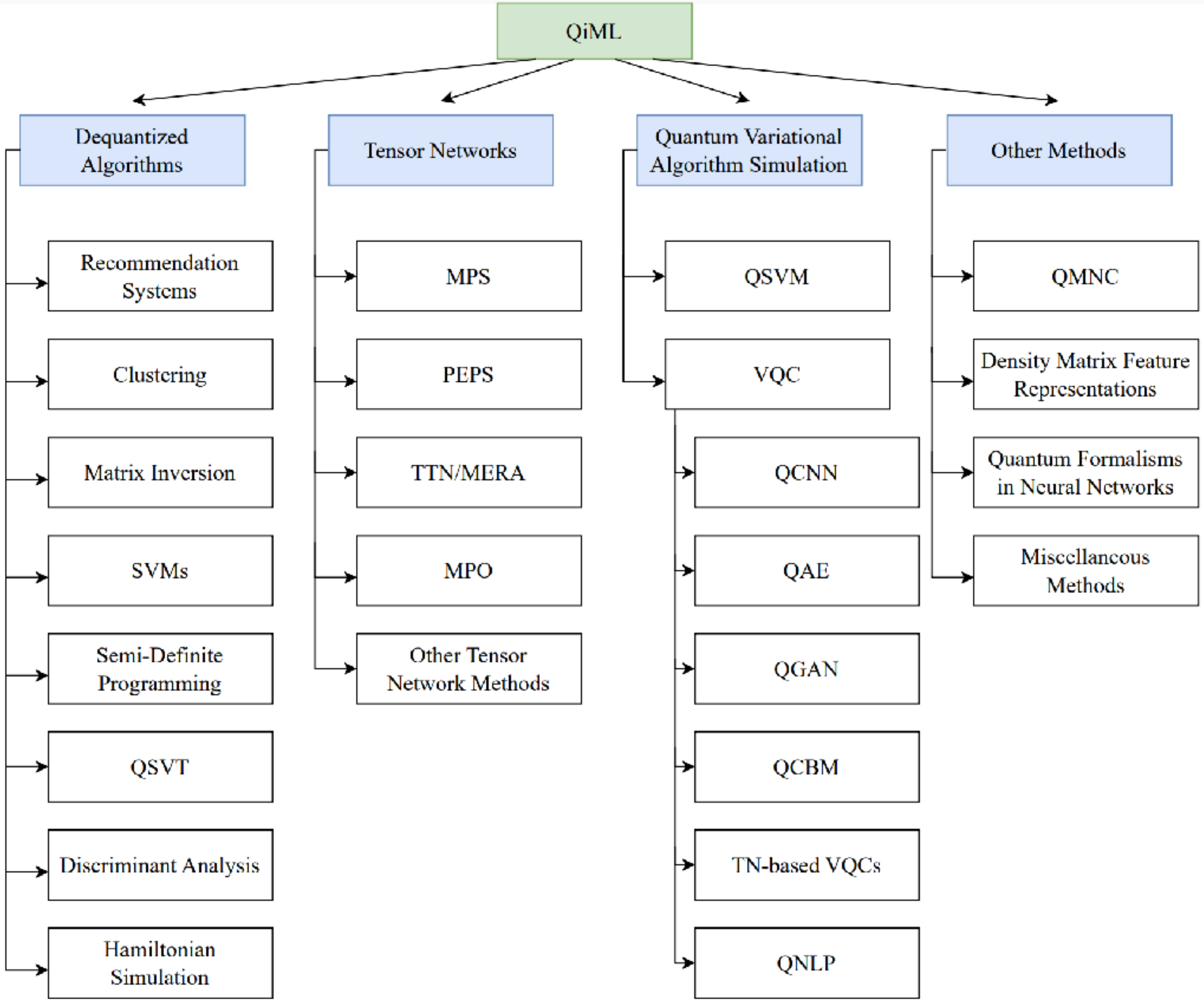
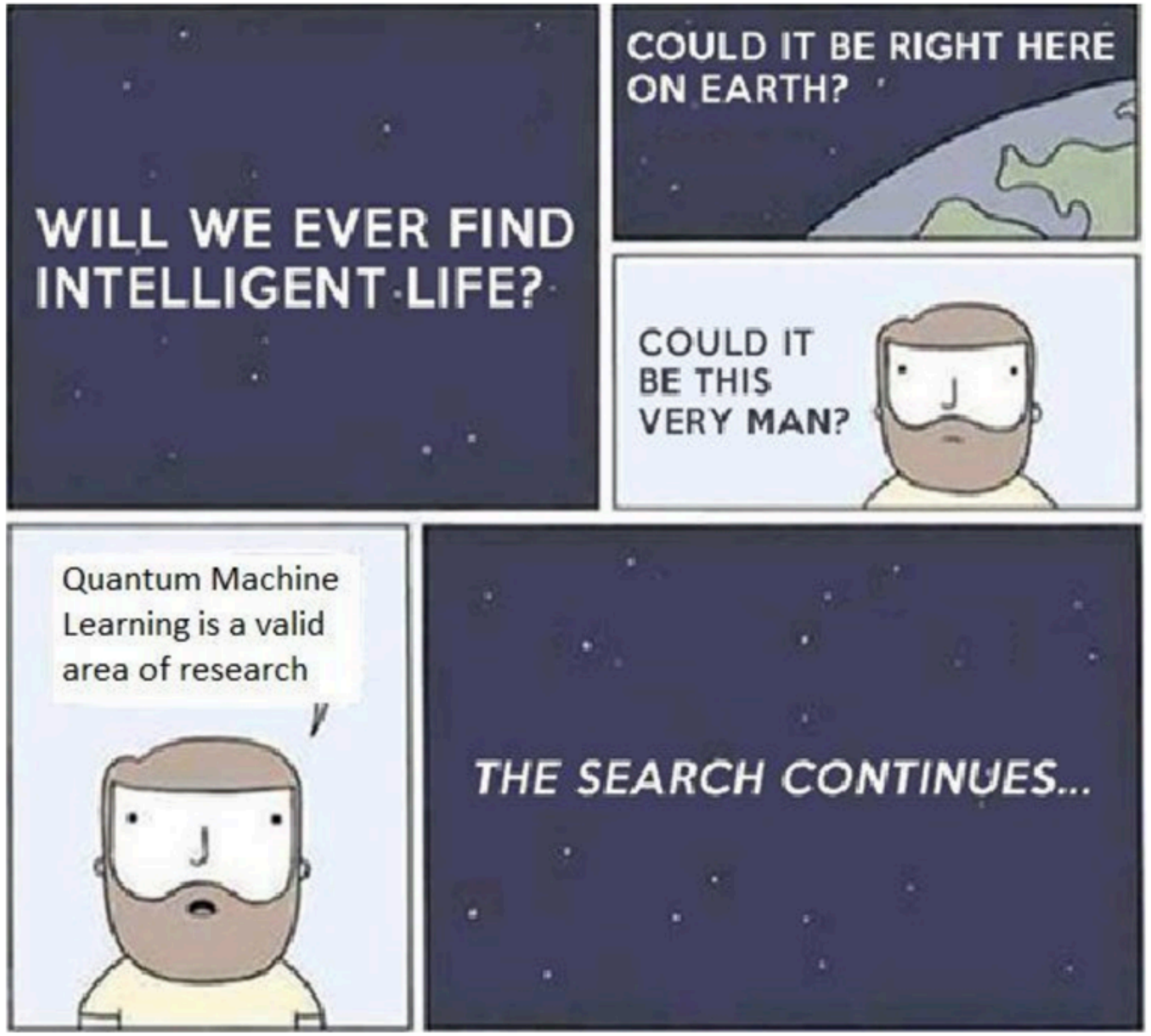
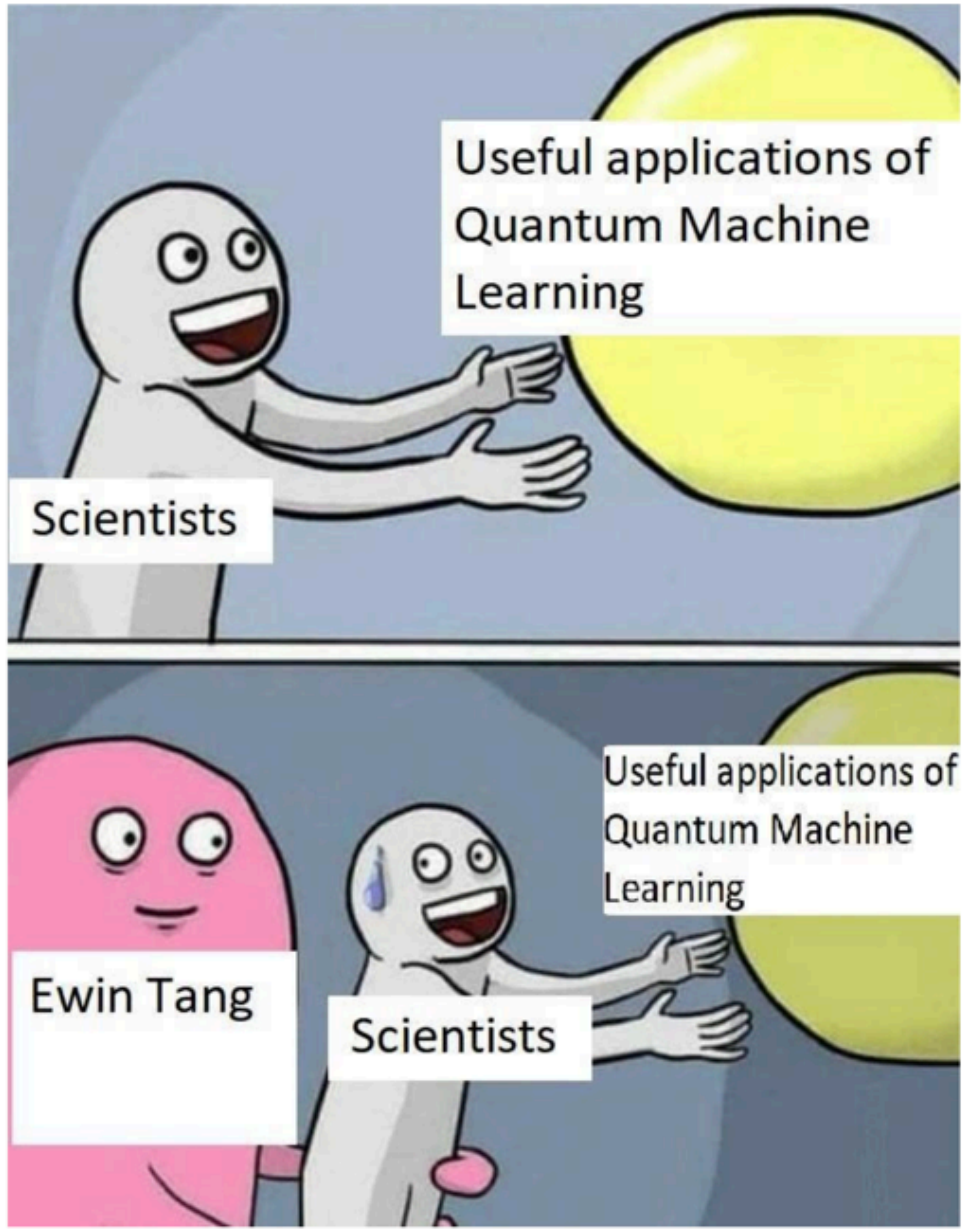


Fig. 3

Quantum Inspired





https://arthurpesah.me/assets/pdf/qml-talk-vannes-2020.pdf

Quantum Enhanced

Sharma 2020

Quantum-Enhanced Machine Learning (QEML) involves taking supervised learning algorithms and making them more efficient through the use of quantum gates and orthogonal transformations to achieve more meaningful results.

ChatGPT

Quantum-enhanced machine learning (QEML) refers to the use of quantum computing and quantum algorithms to improve various aspects of machine learning, including model training, inference, and optimization. QEML aims to leverage the unique properties of quantum systems, such as superposition and entanglement, to enhance the performance and efficiency of machine learning tasks beyond what is achievable with classical methods alone.

Sharma 2020, QEML: (Quantum Enhanced Machine Learning) Using Quantum Computation to implement a K-nearest Neighbors Algorithm in a Quantum Feature Space on Superconducting Processors

Full Quantum

Définition

Un algorithme dont l'ensemble de l'apprentissage et du circuit sont quantiques

Une super application inutile

who and when	architecture	algorithm	input data	comment
Google, Oct 2019	Sycamore, 53 superconducting qubits	cross entropy benchmarking	**none**	running a random gates algorithm
China, December 2020	70 photons modes GBS (Gaussian Boson Sampling)	interferometer photons mixing	**none**	running a random physical process
IBM Research, December 2020	IBM 27 superconducting qubits	symmetric Boolean functions	SLSB3 function parameters	**theoretical demonstration of quantum advantage**
Kerenidis, Diamanti et al, March 2021	multi-mode photon dense encoding of verified solution	Quentin Merlin Arthur based verification	output from some quantum computation (not implemented)	**no actual computing done in the experiment**
China, April 2021	Quantum walk on 62 superconducting qubits	simple quantum walk	simulating a 2-photons Mach-Zehnder interferometer	**no quantum advantage at all**
University of Arizona, May 2021	supervised learning assisted by an entangled sensor network	variational algorithm, classical computing	data extracted from three entangled squeezed light photonic sensors	**not a quantum « computing » advantage per se**
China, June 2021	66 superconducting qubits and 110 couplers, Zuchongzhi 1, then 2.1	cross entropy benchmarking	**none**	56 used qubits
China, September 2021				60 used qubits
China, June 2021	144 photons modes GBS and up to 113 detected events	interferometer photons mixing	**none**	**parametrizable photon phases could lead to a programmable system**

References

[1] https://www.politico.com/newsletters/digital-future-daily/2023/10/03/checking-in-on-the-quantum-hype-00119742

[2] https://quantumzeitgeist.com/the-quantum-hype-machine/

[3] https://s3.amazonaws.com/external_clips/3667813/Quantum_machine_learning_3.pdf?1610373485

[4] https://arthurpesah.me/assets/pdf/qml-talk-vannes-2020.pdf

[5] Huynh et al., 2023, Quantum-Inspired Machine Learning: a Survey, https://arxiv.org/pdf/2308.11269.pdf

[6] Sharma 2020, QEML: (Quantum Enhanced Machine Learning) Using Quantum Computation to implement a K-nearest Neighbors Algorithm in a Quantum Feature Space on Superconducting Processors https://arxiv.org/pdf/2002.10453.pdf

[7] Ezratty, 2022, Mitigating the quantum hype, https://arxiv.org/pdf/2202.01925.pdf