#### Lecture 25

#### Basics of Machine Learning and Quantum Machine Learning

of the course "Fundamentals of Quantum Computing" (by and QUANTERALL)

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INSTITUTE for ADVANCED PHYSICAL STUDIES



January 27, 2023



Machine Learning

Machine Learning using Quantum Computers

#### Machine Learning

- Machine learning is a "Field of study that gives computers the ability to learn without being explicitly programmed." Samuel, Arthur (1959). "Some Studies in Machine Learning Using the Game of Checkers". IBM Journal of Research and Development. 3 (3): 210–229. doi:10.1147/rd.33.0210

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- A computer program is said to learn from experience  $\mathbf{E}$  with respect to some class of tasks  $\mathbf{T}$  and performance measure  $\mathbf{P}$  if its performance at tasks in  $\mathbf{T}$ , as measured by  $\mathbf{P}$ , improves with experience  $\mathbf{E}$ .

Mitchell, T. (1997). Machine Learning. McGraw Hill. p. 2. ISBN 978-0-07-042807-2

#### Definitions





#### SUPERVISED LEARNING



Machine learning that are designed to learn by examples, i.e., it maps the input to an output based on previous input-output pairs.

#### Unsupervised learning. Clustering



#### Unsupervised learning. Generative.



Machine learning that let the model discover and learn on their own, i.e., it works on its own to discover pattern and information .

#### Reinforcement Learning



In some applications, the output of the system is a sequence of actions the learning in which machine is able to assess the goodness of past approaches or policies and learn from past good action sequences to be able to generate a policy.

#### Methods



#### O'REILLY"

#### Hands-On Machine Learning with Scikit-Learn & TensorFlow

CONCEPTS, TOOLS, AND TECHNIQUES TO BUILD INTELLIGENT SYSTEMS

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#### AI-ML-DL

#### **Artificial Intelligence**

#### **Machine Learning**

#### **Deep Learning**

The subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like speech and image recognition, by exposing multilayered neural networks to vast amounts of data. A subset of AI that includes abstruse statistical techniques that enable machines to improve at tasks with experience. The category includes deep learning Any technique that enables computers to mimic human intelligence, using logic, if-then rules, decision trees, and machine learning (including deep learning)

#### ML-DL



#### Frameworks



#### Favourite machine learning frameworks

(based on data from Kaggle survey 2019)



#### % PyTorch Papers of Total TensorFlow/PyTorch Papers

2021 Qiskit Global Summer School on Quantum Machine Learning Kernel methods Quantum Machine Learning course (IBM) Kernel methods, Generative networks

2021 Qiskit Global Summer School on Quantum Machine Learning Kernel methods Quantum Machine Learning course (IBM) Kernel methods, Generative networks Maria Schuld Francesco Petruccione Machine Quantum chine Learning: Learning Annlied with Quantum Computers Second Edition Springer Apress kernel methods lin. regr., k-means, QNN

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kernel methods lin. regr., k-means, QNN Vedran Dunjko, Jacob M. Taylor and Hans J. Briegel, Quantum-Enhanced Machine Learning, Physical Review Letters 117 (13), 130501 (2016) doi:10.1103/PhysRevLett.117.130501 arXiv:1610.08251

# Building a quantum classifier

Amira Abbas

IBM Quantum, University of KwaZulu-Natal



## Hilbert space is a big place!

- Carlton Caves

With just 275 qubits, we can represent more states than the number of atoms in the observable universe





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Image credit: Maria Schuld and Francesco Petruccione. Supervised learning with quantum computers. Vol. 17. Springer, 2018.

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### Noisy, error-prone, small devices

What can we do now?





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# Variational models

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## Variational models







## Variational circuit as a classifier



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#### 🕀 Qiskit

## Variational circuit as a classifier

- **Task:** Train a quantum circuit on labelled samples in order to predict labels for new data
- Step 1: Encode the classical data into a quantum state 🛛 🖈
- Step 2: Apply a parameterized model
- Step 3: Measure the circuit to extract labels
- **Step 4:** Use optimization techniques (like gradient descent) to update model parameters



## Data encoding





Applying a variational model





## Applying a variational model



Sim et al. "Expressibility and Entangling Capability of Parameterized Quantum Circuits for Hybrid Quantum-Classical Algorithms." Advanced Quantum Technologies 2.12 (2019): 1900070.

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### Applying a variational model



Sim et al. "Expressibility and Entangling Capability of Parameterized Quantum Circuits for Hybrid Quantum-Classical Algorithms." Advanced Quantum Technologies 2.12 (2019): 1900070.

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## Extracting labels





Source: Havliček, Vojtěch, et al. "Supervised learning with quantum-enhanced feature spaces." Nature 567.7747 (2019): 209-212.

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# THANK YOU FOR YOUR ATTENTION!

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