Qiskit Machine Learning: Quantum algorithms for supervised learning

Organisers

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Abstract

Today, machine learning applications touch almost every angle of business, science, and private life, ranging from speech and image recognition to generative models to improve drug design. Machine learning's primary goal is to train computers to make sense of an ever-expanding pool of data. However, in order to learn from these increasingly complex datasets, the underlying models, such as deep neural networks, also become more sophisticated and expensive to train.

Quantum computation offers a potential avenue to increase the power of machine learning models, and the corresponding literature is growing at an incredible pace. Quantum machine learning (QML) proposes new types of models that leverage quantum computers' unique capabilities to, for example, work in exponentially higher-dimensional feature spaces to improve the accuracy of models

Qiskit Machine Learning is a new application module builds on top of Qiskit's existing functionality to create and run (parametrized) quantum circuits, evaluate complex observables, and also automatically evaluate the corresponding gradients with respect to circuit parameters. Qiskit Machine Learning introduces fundamental computational building blocks - such as Quantum Kernels and Quantum Neural Networks - used in different applications, including classification and regression. We will review a Quantum Support Vector Machine algorithm that require a feature map for which computing the kernel is not efficient classically. This means that the required computational resources are expected to scale exponentially with the size of the problem. QSVM uses a Quantum processor to solve this problem by a direct estimation of the kernel in the feature space and potentially may achieve quantum advantage. Another key component is the Torch Connector, which allows users to integrate all of our quantum neural networks directly into the PyTorch open source machine learning library.

In this workshop we present core components of Qiskit Machine Learning and build several machine learning models for classification and regression purposes. Also, we show how to build a hybrid neural network with classical and quantum layers and train this model on a well-known MNIST dataset. After this workshop a user will able to build their own quantum machine learning models for small datasets.

Goals of the Workshop

We cover the basic concept of classical supervised learning and review quantum algorithms for machine learning in the first half. We explain a workflow to construct an ML model, train it with Qiskit Machine Learning using a simulator or a real device, and interpret the results in the second half of the workshop. The goal of this tutorial is that participants get to used to their own (small) quantum machine learning problems and solve them with Qiskit Machine Learning module.

Schedule of the Tutorial

14:00- 15:30(90 min): Introduction to Quantum Machine Learning for supervised learning

- Recap of classical machine learning
    - What is supervised learning.
    - How we train machine learning models.
    - Classical methods for supervised learning.

- Introduction to quantum machine learning
    - What is quantum machine learning.
    - Variational algorithms.
    - Data encoding.
    - Quantum measurements.
    - Optimization methods.
    - Kernel methods and Support Vector Machines.

- Introduction to neural networks
    - Classical neural networks.
    - Quantum circuits for neural networks.

- Q&A and Material Review

15 min break

15:45 – 17:00 (75 min): Hands-on with Qiskit Machine Learning

- Introduction to Qiskit Machine Learning and the software design of the module:
    - Overall design of Qiskit machine learning.
    - Overview of Quantum Kernel package.
    - Constructing Neural networks.
    - Machine learning algorithms: classifiers and regressors.
    - PyTorch connector for hybrid neural networks.
    - Overview of quantum generative adversarial networks.

- Coding Up a supervised learning model
    - Kernel methods for Support Vector Machines.
    - Building up a neural network for classification/regression.
    - Training a hybrid PyTorch model for MNIST dataset classification problem.

- Final Remarks and Qiskit Machine Learning Roadmap

Prerequisite from Participants

Proficiency in quantum computing, python, machine learning.