Hands-On Introduction to Quantum Machine Learning

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Abstract

This tutorial will cover a hands-on introduction to quantum machine learning. Foundational concepts of quantum information science (QIS) will be presented (qubits, single and multiple qubit gates, measurements, and entanglement). Building on that, foundational concepts of quantum machine learning (QML) will be introduced (parametrized circuits, data encoding, and feature mapping). Then, QML models will be discussed (quantum support vector machine, quantum feedforward neural network, and quantum convolutional neural network). All the aforementioned topics and concepts will be examined using codes ran on a quantum computer simulator. All the covered materials assume novice audience who are interested to learn about QML. Further reading and software packages and frameworks will also be shared with the audience.

Description of the Proposed Tutorial

QML has witnessed great successes in the past couple of years and as such has gained significant attention from academia and industry. However, all the principals of QML are based on QIS. As such, this tutorial aims to present a smooth introduction to QIS and its applications in QML. Further, state-of-the-art QML models will be presented with code examples. This tutorial is meant to encourage academics and students to further explore QML. The goals of the tutorial are as follows:

- Learn foundational concepts of quantum information science and quantum machine learning.
- Gain hands-on experience with coding on a quantum computer simulator.
- Understand the principles behind key QML models such as quantum support vector machines and quantum neural networks.
- Access resources for further learning and explore relevant software packages and frameworks.

General description of tutorial content

In this tutorial, we embark on a comprehensive exploration of QML, covering foundational concepts to advanced algorithms. Our journey begins with a solid foundation in quantum computing essentials, including qubits, single and multiple qubit gates, measurements, and entanglements. Moving forward, we introduce the concept of parameterized circuits, offering flexibility and adaptability crucial for quantum machine learning tasks. Finally, we discuss data encoding strategies and feature mapping techniques essential for translating classical data into the quantum domain.

In the second part, we transition from theory to practice. We will explore various quantum machine learning models ready to revolutionize data analysis. We will begin with the Quantum Support Vector Machine, examining how it modifies the classical SVM for classification tasks. Next, we will delve into the Quantum Feed-forward Neural Network, designed for intricate pattern recognition, and explore Quantum Convolutional Neural Networks, tailored specifically for processing structured data such as images.

Content Level and Audience Prerequisites

The tutorial's content level is designated for beginners, comprising approximately 70% beginner, 30% intermediate, and 0% advanced material. The tutorial is designed for practitioners and researchers with a basic understanding of machine learning concepts. The tutorial will comprehensively cover all essential quantum information science material.

Outline

Total Duration 3 hrs

1. Part 1 (90 minutes):
   (a) Qubits, single and multiple qubit gates, measurements, entanglement
   (b) Parameterized circuits
   (c) Data encoding and feature mapping
2. Part 2 (90 minutes):
   (a) Quantum Support Vector Machine
   (b) Quantum Feed-forward Neural Network
   (c) Quantum Convolutional Neural Network
   (d) Concluding Remarks