Hands-On Introduction to Quantum Machine Learning

***Abstract*—This tutorial offers a hands-on introduction into the captivating field of quantum machine learning (QML). Beginning with the bedrock of quantum information science (QIS)—including essential elements like qubits, single and multiple qubit gates, measurements, and entanglement—the session swiftly progresses to foundational QML concepts. Participants will explore parameterized or variational circuits, data encoding or embedding techniques, and quantum circuit design principles. Delving deeper, attendees will examine various QML models, including the quantum support vector machine (QSVM), quantum feed-forward neural network (QNN), and quantum convolutional neural network (QCNN). Pushing boundaries, the tutorial delves into cutting-edge QML models such as quantum recurrent neural networks (QRNN) and quantum reinforcement learning (QRL), alongside privacy-preserving techniques like quantum federated machine learning, bolstered by concrete programming examples. Throughout the tutorial, all topics and concepts are brought to life through practical demonstrations executed on a quantum computer simulator. Designed with novices in mind, the content caters to those eager to embark on their journey into QML. Attendees will also receive guidance on further reading materials, as well as software packages and frameworks to explore beyond the session.**

***Index Terms*—Quantum machine learning, neural networks, reinforcement learning, federated learning.**

I. TUTORIAL SUMMARY

Participants will delve into the realm of quantum machine learning (QML) through immersive hands-on sessions using a quantum computer simulator. This tutorial offers a holistic approach, beginning with the fundamental principles of quantum information science (QIS), progressing to pivotal QML concepts, exploring diverse QML models, and culminating in practical coding demonstrations. Tailored for newcomers possessing a foundational understanding of machine learning, this tutorial serves as a gateway for those eager to venture into the captivating domain of QML.

II. TUTORIAL CONTENTS LEVEL

The tutorial's content level is designated for beginners, comprising approximately 33% beginner, 33% intermediate, and 33% advanced material. The tutorial session will kick off with in-depth introductory presentations, providing a thorough understanding of the basics of quantum machine learning (QML). Attendees will have the opportunity to grasp these concepts through hands-on demonstrations featuring a variety of practical examples. Following this, intermediate and advanced sessions will dive into the cutting-edge research methodologies in QML. Tailored examples will be provided, enabling participants to actively engage with the content and potentially apply it to elevate their own research endeavors.

III. TUTORIAL TARGET AUDIENCE

The tutorial is designed for practitioners and researchers with a basic understanding of machine learning concepts. Attendees should have a general knowledge of linear algebra but no prior experience in quantum computing or quantum machine learning is required. The tutorial aims to empower participants with the skills needed to start working on quantum machine learning projects.

IV. TUTORIAL GOALS

- Learn foundational concepts of quantum information science, quantum computing 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 (QSVM) and quantum neural networks (QNN).
- Acquire proficiency in advanced QML designs and models, and glean insights into their practical application within participants' own research endeavors.
- Access resources for further learning and explore relevantsoftware packages and frameworks.

V. TUTORIAL RELEVANCE

This tutorial is highly relevant to practitioners and researchers in quantum computing, quantum engineering and machine learning, providing them with the necessary skills to leverage quantum machine learning in their projects. The tutorial bridges the gap between classical machine learning and quantum computing, enabling attendees to apply QML techniques in real-world scenarios.

VI. TUTORIAL FORMAT

The tutorial will combine slides, handouts, and online materials for theoretical aspects. The hands-on portion will involve coding examples on a quantum computer simulator.

VII. TUTORIAL CONTENTS

Total Duration 3 hrs

1) Part 1 (First 60 minutes):
   a) Qubits, single and multiple qubit gates, measurements, entanglement
   b) Parameterized or variational quantum circuits
   c) Data encoding or embedding and quantum circuitdesign
2) Part 2 (Second 60 minutes):
   a) Quantum Support Vector Machine
   b) Quantum Feed-forward Neural Network
   c) Quantum Convolutional Neural Network
3) Part 3 (Second 60 minutes):
   a) Quantum Recurrent Neural Networks
   b) Quantum Reinforcement Learning
   c) Quantum Federated Learning
   d) Concluding Remarks