Introduction to Quantum Machine Learning & VQE

Quantum Software Development Journey: From Theory to Application with Classiq - Part 3

Program Overview

Quantum Software Development Journey: From Theory to Application with Classiq

- Week 1: Introduction to the Classiq Platform & High-Level Functional Design
- Week 2: Git & GitHub - Software Development Skills
- **Week 3: Introduction to Quantum Machine Learning and VQE**
- Week 4: QNN and Advanced Applications

Session Overview

Introduction to Quantum Machine Learning and VQE

Introduction - 30 min

- What is it QML?
- What is it VQE?

Hand-On Practice - 60 min

- VQE Implementation with Classiq

Let's practice!

Quantum Machine Learning

- QML: The intersection between quantum computing and machine learning
- Mostly referred to ML algorithms for the analysis of **classical** data executed on/ assisted by a **quantum** computer

Type Algorithm

Type Data	classical	quantum
classical	**CC**	**CQ**
quantum	**QC**	**QQ**

Machine Learning - Basic Concepts

- Learning from data to make predictions or decisions, rather than following a step-by-step instruction set (as in classical coding)
- Key Concepts:
  - Training Data
  - Features (predictors) and Labels (target variable), E.g. House pricing:
    - Features: Size of the house, number of bedrooms, location, age of the house, etc.
    - Labels: The actual price of the house (a continuous numerical value)
  - **Training** and Testing Phases
  - Model Evaluation

Training Machine Learning Model

- Initializing Model Parameters
  - Setting initial values for the parameters that the model will learn.
- Forward Propagation
  - Passing the input data through the model to get predictions
- Calculate Loss
  - Measuring the difference between the model's predictions and the actual target values using a loss function.
- Backpropagation and Optimization
  - **Adjusting the model parameters to minimize the loss using optimization algorithms like gradient descent.**

Parametric Quantum Circuits (PQC)

- Quantum circuits composed of parameterized gates
  - Such as: $R_X(\boldsymbol{\theta})$, $R_Y(\boldsymbol{\theta})$, $R_Z(\boldsymbol{\theta})$, controlled rotations and etc.
- Training these parameters: **A circuit capable of learning!**
- **Ansatz:** Specific form of a PQC tailored for a particular problem:
  - Represents a hypothesis about the structure of the quantum state or the solution space.
  - Designed to efficiently explore the solution space with a minimal number of parameters.

Variational Quantum Eigensolver (VQE)

- VQE is used to find the ground state energy of quantum systems
  - Choose PQC which capture the Hamiltonian of a system
  - Calculate The expectation value
  - Classical optimizer

- Encoding other information in the Hamiltonian and anzatz (QAOA)

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THANK YOU

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