COURSE: ECE730/QIC890-T36

COURSE TITLE: **Quantum Machine Learning**

INSTRUCTOR: Prof. Na Young Kim
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Note: Do not use LEARN email to reach the instructor

LECTURES: 10-11 Lectures, HH:MM-HH:MM, Locations (MM/DD/YYYY-MM/DD-YYYY)

DESCRIPTION

The course introduces basic classical and quantum machine learning algorithms for solving real-life problems. Classical machine learning algorithms are programmed using Sci-Kit Learn and/or PyTorch/TensorFlow based on Python. The elements of quantum circuits (qubits, single-qubit gates, two-qubit gates, and quantum operators) are introduced. A quantum programming language (one of three options: Qiskit, Pennylane, or #q) is used to implement quantum machine learning algorithms. Then, hybrid classical and quantum algorithms are studied and programmed using quantum simulators and/or real quantum computers through a cloud service such as IBM Q Experience, Amazon Bracket, or Xanadu Pennylane.

COURSE OBJECTIVE

The course is developed for students to

- Learn some basic classical machine learning algorithms;
- Learn quantum versions of classical machine learning algorithms;
- Program classical and quantum machine learning algorithms;
- Apply these techniques to a simple real-life problem as a term project.

Expected Background: Python programming, Some familiarity with basic quantum information processing and basic quantum circuit models, Introduction to classical machine learning

(Tentative) **SYLLABUS**

1. **PART 1: Basic Foundation of Classical and Quantum Programming Interfaces** (2 weeks)
   a. Overview of Classical and Quantum Machine Learning
   b. Introduction to Classical Machine Learning Programming
      i. Sci-Kit Learn
   c. Introduction to Quantum Programming
      i. Introduction to Quantum Computing
      ii. Fundamentals of Quantum Algorithms
      iii. Quantum Circuits
      iv. Qiskit/Pennylane

2. **PART 2: Classical and Quantum-Inspired Machine Learning Algorithms** (7 weeks)
   a. Linear Algebra Subroutines
      i. Classical Fast Fourier Transform
      ii. Quantum Fourier Transform Algorithm
   b. Supervised machine learning algorithms
      i. Classical Support Vector Machines
      ii. Quantum Support Vector Machines
   c. Unsupervised machine learning algorithms
      i. Classical Principal component analysis
      ii. Quantum Principal component analysis
   d. Neural Networks
      i. Classical Neural Networks
      ii. Quantum Neural Networks

3. **PART 3: Hybrid Classical-Quantum Machine Learning Algorithms** (2 weeks)
    a. Quantum Approximate Optimization Algorithm
        i. MAX-Cut problem
    b. Variational Quantum Eigensolver Algorithm
        i. H_2 molecule

TEXTBOOK

None required. Article handouts provided and lecture slides will supplement course lectures.

RESOURCES

Qiskit tutorials for quantum machine learning: https://qiskit.org/learn/course/machine-learning-course/
Sci-Kit user guides for classical machine learning: https://scikit-learn.org/stable/user_guide.html

GRADE DISTRIBUTION

Assignments: 30%
Term Presentation: 20%
Final: 50%

COURSE WEBSITE

The course homepage is on LEARN, where the course syllabus, lecture notes, and assignments are uploaded. Any important updates will be announced as well.

(Tentative) **GRADE DISTRIBUTION**

- 4-5 **Assignments:** 30%

  Late Policy

  $S(t) = S(0)*(10-t)*0.1$ if $t < t_s$ or $S(t) = 0$ if $t > t_s$,
  where $t = 0$ is the due date, t is the turn-in date, and t_s is the feedback posting date.

  An exception to this policy can be made in special circumstances by contacting the instructor in advance.
  Note that any evidence violating the Honor code (e.g. plagiarism, copying and etc.) will yield $S(t) = 0$ regardless of t.

- **Mid-term Presentation**: 20%
    - **Mid-term Presentation (MM/DD/YYYY)** 10%
    - **Mid-term Report (Due: MM/DD/YYYY)**: 10%

- **Final: 50%**
    - **Final Oral Presentation MM/DD/YYYY:** 25%
    - **Final Term Paper (Due: MM/DD/YYYY):** 25%

UW POLICY 71-STUDENT DISCIPLINE

https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71

We honor this policy throughout the course.