# Quantum machine learning

**Academic Year: ( 2023 / 2024 )** **Review date: 24-04-2023**

**Department assigned to the subject: Physics Department**

**Coordinating teacher: TORRONTEGUI MUÑOZ, ERIK**

**Type: Electives ECTS Credits : 3.0**

**Year : 2 Semester : 1**

## REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Calculus
Quantum physics
Advanced quantum physics
Basic programming knowledge in Python

## DESCRIPTION OF CONTENTS: PROGRAMME

Part 1.- Introduction to quantum computing
- General idea. Types of quantum computing.
- Quantum gates and circuits
- Quantum programming languages
Part 2.- Variational quantum algorithms
- Introduction to variational quantum algorithms
- Quantum Approximate Optimization Algorithm and Variational Quantum Eigensolver
- Issues with VQA¿s: Barren plateaus, expressivity and measurements
- Example of potential applications
Part 3.- Quantum Support Vector Machines and Kernel Methods
- Intro to classical Kernel Methods
- Quantum Kernel Methods
- Quantum support vector machines and classifiers
Part 4.- Unsupervised Quantum Machine Learning
- Unsupervised classical machine learning and generative models
- Quantum generative models and quantum Born Machines
- Quantum generative adversarial networks
Part 5.- Quantum Neural Networks
- Quantum Neural Network classifier
- Data re-uploading
- Convolutional quantum neural networks
- Quantum optical neural networks
Part 6.- Recent advances in the field and outlook

## LEARNING ACTIVITIES AND METHODOLOGY

Educational activities:
- Theory lessons
- Tutorial sessions
- Practical quantum programming activities
- Individual student work

Educational Methodologies:
- Classroom lessons by lecturers in which the main concepts will be developed. Bibliography will be provided to students as a complement to the main lessons
- Solution of practical exercises in the classroom and also individually by students.
- Practices on quantum programming.

## ASSESSMENT SYSTEM

SE1. Class participation
SE2. CONTINUOUS EVALUATION. Assesses papers, projects, class presentations, debates, exercises, internships and workshops throughout the course.
SE3. FINAL EXAM. Global assessment of knowledge, skills and capacities acquired throughout the

course.

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|---|---|
| **% end-of-term-examination:** | 60 |
| **% of continuous assessment (assigments, laboratory, practicals…):** | 40 |

## BASIC BIBLIOGRAPHY


- Elena Peña Tapia, Giannicola Scarpa, Alejandro Pozas-Kerstjens, A didactic approach to quantum machine learning with a single qubit, https://arxiv.org/abs/2211.13191, 2022
- J. Biamonte et al Quantum machine learning, Nature 549, 195 , 2017
- M. Cerezo et al Variational quantum algorithms, Nature Reviews Physics 3, 625 , 2021


## ADDITIONAL BIBLIOGRAPHY


- M. Cerezo et al., Challenges and opportunities in quantum machine learning, Nature Computational Science 2, 567, 2022
- M. Schuld, Supervised quantum machine learning models are kernel methods, https://arxiv.org/abs/2101.11020, 2021
- Schölkopf, Bernhard, and Alexander J. Smola Learning with kernels: support vector machines, regularization, optimization, and beyond, Smola MIT Press, 2002


## BASIC ELECTRONIC RESOURCES

- . pennylane: https://pennylane.ai/qml/quantum-machine-learning.html
- . qiskit: https://qiskit.org/learn/