COURSE SYLLABUS

AI Models for Physics

2425-1-F9102Q022

Aims

The aim of this course consists of providing a set of general artificial intelligence methods to be applied to physical systems including quantum systems. The course prepares to conduct a professional approach to match most suitable machine learning tools to a physical problem. It enables to apply artificial intelligence in both scientific research and applied science environments, including reinforcement learning and quantum machine learning.

Contents

The course is divided in four main topics: (1) deep supervised learning by convolutional and graph neural networks and symbolic models, (2) unsupervised learning with particular emphasis with the Ising model and the restricted Boltzmann machines, (3) application of deep reinforcement learning to control of quantum systems, and (4) quantum machine learning. Practical applications ranging from (and not limited to) econophysics to quantum technologies are included.

Detailed program

Supervised learning - Convolutional networks for hyper-resolution of scientific images, the case of galaxy classification, graph neural networks, automated discovery of physical laws by symbolic models
Unsupervised learning – The Ising model, Markov chains, Metropolis algorithm, Gibbs sampling. Restricted Boltzmann machines for unsupervised learning. Autoencoders.
Reinforcement learning - Bellman equation, Reinforcement learning algorithms, density matrix formalism, master equation of quantum systems, coherent control of quantum states
Quantum Machine Learning: quantum generative adversarial networks for generation of approximated distributions, training of variational quantum circuits for generation of entangled data, quantum support vector machines

Epistemological aspects

Prerequisites

Supervised learning methods, unsupervised learning methods, principles of quantum mechanics
Last part on quantum machine learning takes advantage of the first part of the Quantum Simulation Course, held during the same semester.

Teaching form

Lectures and laboratory programming activity. Both of them will be held in presence. Attendance both to lectures and practical examples is warmly recommended.
The programming activity refers to the program by computational lessons in which students can simulate the models. The computational part will take place in Python.

Textbook and teaching resource

https://www.deeplearningbook.org/ (free online)
W. L. Hamilton, Graph Representation Learning (free PDF online) https://www.cs.mcgill.ca/~wlh/grl_book/files/GRL_Book.pdf
Algorithms for reinforcement learning (free PDF online) https://sites.ualberta.ca/~szepesva/papers/RLAlgsInMDPs.pdf
Peter Wittek, Quantum Machine Learning: What Quantum Computing Means to Data Mining
Publisher: Academic Press ISBN: 9780128009536 (free PDF online)

Semester

Second

Assessment method

Students are required to present a programming project based on topics of the course, the exam will then consist in (1) a short report and a presentation on the project, and (2) oral questions on the topics covered during lectures.

Office hours

Wednesday 17:00-18:00

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE