UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

AI Models for Physics

2627-1-F9103Q022

Aims

The aim of this course consists of providing a set of state-of-the-art 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 physical and statistical problems. It enables to apply artificial intelligence in both scientific research and applied science environments, including graph neural networks, physics informed neural networks, reinforcement learning and quantum machine learning.

Contents

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

Detailed program

Supervised learning - Graph neural networks, physics informed neural nteworks, 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
Reinforcement learning - Markov process, Bellman equation, Reinforcement learning algorithms
Quantum Machine Learning: quantum support vector machines,, quantum reservoir computing, quantum generative adversarial networks for generation of approximated distributions

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 Foundations of Quantum Computing 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 consist of hands-on in which students can apply the methods. 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 focussing on the coding part, and (2) oral questions on the topics covered during lectures.

Office hours

Upon appointment to be agreed some days before

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE