UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Unconventional and Quantum Computing

2627-2-F1802Q140

Aims

Knowledge and understanding
Students will understand the principles underlying the functioning of some unconventional, bio-inspired and quantum computational models.

Applied knowledge and understanding
Students will be able to choose to choose the most suitable computational model to solve an assigned problem.

Independent judgment
Students will acquire the ability to evaluate whether the computational model can efficiently tackle computationally difficult problems.

Communication skills
The great attention paid to formal aspects will allow students to understand the importance of unambiguous communication, using the correct terminology to express the notions and concepts learned.

Learning skills
Establishing a formal theoretical framework will help students developing a the use of deductive learning strategies.

Contents

Notions and concepts at the base of the Theory of Computation, and of the Theory of Computational Complexity, applied to unconventional and quantum computational models. The course also provides the conceptual and theoretical tools that allow to understand the mathematical bases on which the definition of the computational models examined is based.

Detailed program

For the Unconventional Computing part:
• Introduction: classical, sequential and parallel computing architectures
• Unconventional Computing Problems
• DNA Computing: Adleman experiment, Lipton algorithm
• Cellular Computing
• Membrane systems: standard model, membrane systems for computationally complex problems
• Spiking neural P systems
• Genetic Algorithms, Neural Networks
• Social Algorithms

For the Quantum Computing part:
• Quantum physical phenomena, quantum parallelism, entanglement, measurements
• Mathematical notation: qubit, bra, ket, unit operators
• Quantum gates, their representation, and corresponding operators
• Quantum circuits
• Fundamental quantum algorithms: quantum Fourier transform, Shor's algorithms (factorization and discrete logarithms), Grover's algorithm
• Notes on other models: Quantum Turing machines, adiabatic Turing machines, ...
• Programming languages, libraries, simulators, platforms (in particular: QCEngine, Qiskit)
• Hybrid neural networks, and quantum machine learning

Prerequisites

Topics explained in mathematics courses held in the laurea degree in Informatics. It is useful - but not necessary - to have basic notions of theoretical computer science (in particular, Turing machines).

Teaching form

The expected language of instruction is English. However, classes may be conducted in Italian if all students present in the classroom speak Italian and no student requests to attend the lessons in English.

Lectures will be recorded and made available through the e-learning website. The course consists of 24 in-person lectures, each lasting 2 hours, delivered in a traditional (transmissive) teaching format.

Textbook and teaching resource

Textbooks:
• Andrew Adamatzky: Unconventional Computing - A Volume in the Encyclopedia of Complexity and Systems Science, Second Edition. Springer, 2018
• Wolfgang Polak, Eleanor Rieffel: Quantum Computing : A Gentle Introduction. MIT Press, 2011
• Michael A. Nielsen, Isaac L. Chuang: Quantum Computation and Quantum Information. Cambridge University Press, 2010

• Eric R. Johnston, Nic Harrigan, Mercedes Gimeno-Segovia: Programming Quantum Computers: Essential Algorithms and Code Samples. O'Reilly Media, 2019

Lecture notes provided by the teachers.

Semester

Second semester

Assessment method

The learning assessment is based on an oral interview, on the subjects exposed in class during the course. During the interview, the student's ability to explain the topics of the course, and to make brief thoughts on them, will be assessed.

No mid-term assessments are scheduled.

Office hours

On appointment

Sustainable Development Goals

QUALITY EDUCATION