UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Foundations of Quantum Computing

2627-1-F9103Q039

Aims

The aim of this course consists of enabling to identify which architecture (gate model, adiabatic, measurement based) of quantum computer is most suitable for solving a given problem by a quantum algorithm, and to program both simulators of quantum computers and actual quantum computers. Existing quantum hardware basis are introduced. Fundamentals of main quantum algorithms are introduced.

Contents

The mathematical tools of quantum mechanics relevant for quantum computing are introduced, together with their connection with actual up to date hardware. Quantum hardware technologies are compared, with special enphasis on some cases like solid state and atom based quantum computers. The universal quantum Turing machine is introduced. Next, major quantum algorithm with actual implementation are introduced, for both gate model quantum computers and adiabatic quantum computers. Practical examples of implementations of algorithms are developed during the laboratory activity.

Detailed program

Principles of quantum mechanics, the Qubit: Bloch Sphere and Single Qubit Rotations, Two qubits gates, Entanglement,. Di Vincenzo criteria and Physical implementation (Superconducting, atoms), Architectures: Gate model, Adiabatic Quantum Computer, Measurement based (or One Way) Quantum Computer. Fundamental Algorithms: Grover Algorithms, Quantum Fourier Transform, Quantum Phase Estimation, Hadamard test and SWAP test, Quantum annealing algorithms, QUBO problems.

Prerequisites

Linear algebra, Dirac notation of quantum mechanics, unitary operators, Ising model (from the “AI models for Physics” 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 consists of hands-on in which students can apply the models. The computational part will take place in Python. Qiskit and Pennylane environments are used.

Textbook and teaching resource

Nielsen and Chuang “Quantum Computation and Quantum Information”
Rieffel and Polack “Quantum Computing a Gentle Introduction"
Morita and Nishimori, Mathematical Foundation of Quantum Annealing (Free online PDF) https://arxiv.org/pdf/0806.1859.pdf
Stefano Olivares, Lecture Notes on Quantum Computing (Free online PDF) https://sites.unimi.it/olivares/wp-content/uploads/2021/08/lectures_qc_olivares_v5.0.pdf

Semester

Second

Assessment method

Students are required to present one of the laboratory activities at the blackboard and with the code (or alternative, develop an independent project, supported by slides and the code) , the exam will then continue in oral questions on the topics covered during lectures.

Office hours

Available on request by email

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE