UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Quantum Information and Algorithms

2425-2-F9102Q026

Aims

Understanding the peculiarities of Quantum Information. Understanding of the most representative cryptographic protocols used in quantum communication. In-depth understanding of the operating principles of quantum computational models. Understanding the functioning of various classes of quantum algorithms and how they can be implemented using appropriate formalisms and programming languages.

Contents

The course provides an introduction to representative topics in the following thematic areas:

1. Quantum Information Theory (basic elements)
2. Quantum Cryptography (quantum key distribution)
3. Quantum Communication (non-ideal channels and error-correcting codes)
4. Quantum Computation (selected advanced algorithms, Machine Learning algorithms)

Detailed program

1. Quantum Information Theory (basic elements reviewed)
    - From Classical to Probabilistic to Quantum Computations
    - Classical vs. Quantum Correlations
    - Information Quantities in Classical and Quantum Systems

2. Quantum Cryptography (quantum key distribution)

    - Entanglement as a Resource for Cryptography: Teleportation and Dense coding
    - Quantum Key Distribution Protocols: Bennet & Brassard 84, Bennet 92, Ekert 91

3. Quantum Communication (non-ideal channels and error-correcting codes)

    - Density matrix theory
    - Decoherence and Non-Ideal Channels
    - Quantum Error Correcting Codes

4. Quantum Computation (selected advanced algorithms)

```
- Recall of the fundamental concepts
- Quantum “Subroutines” (e.g. phase kick-back)
- Review of “the Canon”, the most well-known algorithms
- Further notable algorithms: the Shor factorization algorithm
```

Prerequisites

Linear algebra, and mathematical topics covered in undergraduate courses held in STEM bachelor degrees. Understanding of basic concepts in statistics and machine learning.

Attendance of the course Fundations of Quantum Computing (1st year M.Sc. a.k.a. Quantum Simulations), or an equivalent course.

Teaching form

The course consists of

- classroom lectures (DE 32 hours)
- interactive laboratory programming activity (DI 24 hours)

All activities will be held in presence.

The course will be delivered in English.

Textbook and teaching resource

Lecture notes and scientific papers provided by the lecturers.

To further explore the topics in greater detail, the following texts are useful:

- Vathsan - Introduction to Quantum Physics and Infromation Processing - CRC Press 2016
- Hayashi - Introduction to Quantum Information Science - Springer-Verlag Berlin Heidelberg 2015
- Wolfgang Polak, Eleanor Rieffel: Quantum Computing : A Gentle Introduction. MIT Press, 2011

Semester

Second Year, First Semester

Assessment method

The learning assessment is based on an oral interview, on the subjects exposed in class during the course.

Evaluation criteria:

- Understanding of Concepts (in-depth and comprehensive understanding of course topics)
- Problem-Solving Skills (application of theoretical knowledge and creativity)
- Ability to Explain and Discuss (clarity, synthesis and critical thinking)

Office hours

Upon appointment.

Sustainable Development Goals

QUALITY EDUCATION | INDUSTRY, INNOVATION AND INFRASTRUCTURE