CS-308

Introduction to quantum computation

Lévêque Olivier, Urbanke Rüdiger

Cursus	Sem.	Type
Communication systems	BA6	Opt.
Computer science	BA6	Opt.
Minor in Quantum Science and Engineering	E	Opt.
Quantum Science and Engineering	MA2, MA4	Opt.

Language of teaching	English
Credits	5
Session	Summer
Semester	Spring
Exam	Written
Workload	150h
Weeks	14
Hours	**4 weekly**
Courses	3 weekly
Exercises	1 weekly
Number of positions	

Summary

The course introduces the paradigm of quantum computation in an axiomatic way. We introduce the notion of quantum bit, gates, circuits and we treat the most important quantum algorithms. We also touch upon error correcting codes. This course is independent of COM-309.

Content

Introduction to quantum computation
- Classical circuit model, reversible computation.
- Quantum bits, Hilbert space of N qubits, unitary transformations, measurement postulate.
- Quantum circuit model, universal sets of gates.
- Deutsch and Josza's problem and algorithm.

Basic algorithms
- Hidden sub-group problem and Simon's algorithm
- Mathematical parenthesis: factoring integers and period of arithmetic functions. Notions on continued fraction expansions.
- Quantum Fourier transform and the period finding algorithm
- Shor's factoring algorithm.
- Grover's search algorithm.

Error correcting codes
- Models of noise and errors.
- Shor and Steane error correcting codes.
- Stabilizer codes.
- Calderbank-Shor-Steane construction.

Keywords

Quantum computation, quantum circuits, universal gates, quantum Fourier transform, Deutsch-Josza's algorithm. Simon algorithm, Shor's algorithm, Grover's algorithm, entanglement, quantum error correction.

Learning Prerequisites

Required courses

Linear algebra course, basic probability course

Important concepts to start the course

Matrices, unitary matrices, eigenvectors, eigenvalues, inner product, algebra of complex numbers

Learning Outcomes

By the end of the course, the student must be able to:
- Explain the concept of quantum algorithm on the circuit model
- Describe universal gates
- Describe basic quantum algorithms
- Compute the evolution of a state through a circuit
- Apply the measurement postulate
- Manipulate algebraic expressions involving the Dirac notation
- Carry out implementation on public NISQ devices
- Give an example of an error correcting code

Teaching methods

Ex cathedra classes. Exercices. Use of IBM Q NISQ devices

Expected student activities

Participation in class, exercise sessions, use of IBM Q NISQ devices

Assessment methods

- Midterm
- Mini project on IBM Q experience
- Written final exam

Supervision

Office hours	No
Assistants	Yes
Forum	Yes
Others	Assistants answer questions during exercise sessions

Resources

Bibliography

N. David Mermin. Quantum Computer Science. An Introduction. Cambridge University Press.
Nielsen and Chuang. Quantum Computation and Information. Cambridge University Press.

Ressources en bibliothèque

- Quantum Computer Science / Mermin
- Quantum Computation and Information / Nielsen

Moodle Link

- https://go.epfl.ch/CS-308