Logbook for the course
Quantum computing
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Contents

1 Lecture notes, bibliography, and exercises

1.1 Lecture notes

The document Lecture Notes is a preliminary version of notes written between 2002 and 2018, for different courses taught at the master in mathematics of the *Université de Rennes 1*. The process of writing is still ongoing.

Although *these lecture notes are not adapted* to the course taught at the *École St Cyr-Coëtquidan*, some chapters can still have some interest to the students attending the SLA-SDI curriculum.

- Chapters 1–4 and 7 and 9 are useful for this cours.
- Part 3, is in an older version using inconsistent notation with respect to the first 4 chapters.

1.2 Bibliography

Other useful sources are the books:

- Michael A. Nielsen and Isaac L. Chuang, Quantum computation and quantum information, Cambridge University Press (2000).
- David McMahon, Quantum computing explained, Wiley-Interscience (2008).

1.3 Exercise handouts

- Handout 01
- Handout 02
- Handout 03
- Handout 04

2 Introduction and motivation

- Short history of computing 1946–today.
- Perspectives. ← End of lecture of 04 December 2018 (morning session).
- Slides of the first lecture.

3 Reminders in classical computing

- Representation of integers as sequences of digits.
- Numerical values of sequences of digits.
- Boolean functions.
- Logical gates and circuits.
- Logical circuit for a addition with carry. ← End of lecture of 04 December 2018 (afternoon session).
- Computing with reversible gates.
- Universality of the Fredkin gate.
- SWAP, controlled-NOT (C-NOT), and controlled-SWAP (C-SWAP) gates.
- Matrix representation of gates.

4 Hilbert spaces

- Complex vector spaces.
- Scalar product on a compex vector space. ← End of lecture of 06 December 2018 (morning session).
- Norm induced by the scalar product.
- Hilbert space.
- Orthonormal families.

- Qbits. Interpretation of their representation. ← End of lecture of 06 December 2018 (afternoon session).
- Tutorial of 06 December 2018 (afternoon session): Handout-01:1–4.
- Linear operators on a Hilbert space.
- Adjoint of an operator.
- Classes of operators: normal, self-adjoint, unitary.
- Positive operators, projections and orthoporjections.
- Eigenvalues, eigenvectors.
- Spectral theorem for self-adjoint operators. ← End of lecture of 14 December 2018.
- Tutorial of 14 December 2018: Handout-01:5–8, Handout-02:1–3.

5 Principles of quantum mechanics

- Statement of the postulates of quantum mechanics.
- Tensor product of Hilbert spaces. ← End of lecture of 20 December 2018.

6 Principles of quantum computing

- Implementation of Boolean functions by logical circuits using gates of small arities.
- Quantum gates and circuits.
  - Hadamard's gate.
  - Phase gate.
  - Controlled gates.
  - Controlled NOT gate.

7 Shor's factoring algorithm

- Discrete Fourier transform.
- Quantum Fourier transform.
- Quantum circuit implementing quantum Fourier transform (QFT).
- Phase estimation algorithm. Uses QFT algorithm as subroutine.
- Order finding algorithm. Uses phase estimation algorithm as an efficient subroutine. It is reminded that order finding is conjectured to be classically an algorithmically difficult problem.
- Factoring is reduced to order finding.
- Presentation of Shor's algorithm.
- Exercises on gates and circuits. ← End of lecture of 11 January 2019.