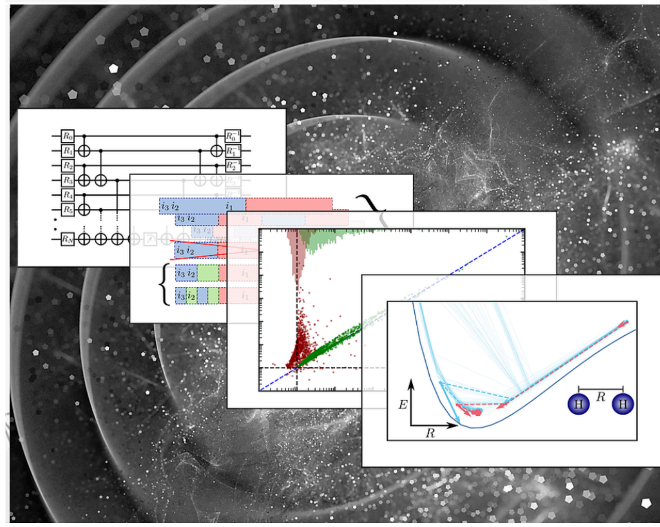
Applied Quantum Algorithms

Applied Quantum Algorithms - Leiden

Bringing quantum algorithms to the real world

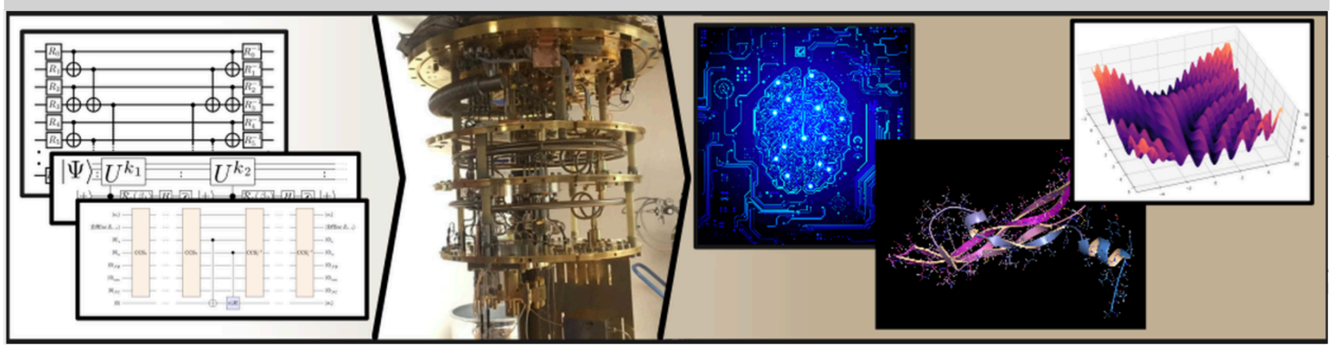


About us

We study quantum algorithms and their applications to problems in natural sciences (physics, chemistry) and practical computing (machine learning, AI, optimization), and methods to make them compatible with near-term quantum devices.

Our vision is to make real-world quantum computing practical, and integrate theory, experiment and applications.

The pipeline
From theory, through implementation, to real-world impact



LIACS, LION, LIC & MI

see https://www.aqa.universiteitleiden.nl/

Today:
About the course & technicalities
Background: computation & quantum physics

About the course & technicalities

Technicalities

Lecturers

Thomas O'Brien
obrien@lorentz.leidenuniv.nl

Vedran Dunjko
v.dunjko@liacs.leidenuniv.nl

Email subject:

use: "aQa:…"

Teaching assistants

Xavier Bonet-Monroig
bonet@lorentz.leidenuniv.nl

Casper Gyurik
c.f.s.gyurik@liacs.leidenuniv.nl

Stefano Polla
polla@lorentz.leidenuniv.nl

Charles Moussa
c.moussa@liacs.leidenuniv.nl

Course web-page(s):

- Blackboard only for grades; link to:
- temporary course page: http://liacs.leidenuniv.nl/~dunjkov/aQa.html
- will make a prettier one.

Technicalities

- **Study materials:**
  - **Nielsen & Chuang "Quantum computation & quantum information"**

  - **Lecture notes/slides/papers/cheat-sheets**

  - **1.1-1.3 of Bruus/Flensberg's "Many-body quantum theory in condensed matter physics"**

  - Additional excellent lecture notes:
    - Ronald de Wolf notes (https://arxiv.org/pdf/1907.09415.pdf)
    - John Preskill notes (http://www.theory.caltech.edu/%7Epreskill/ph219/index.html#lecture)
    - Andrew Childs notes (https://www.cs.umd.edu/~amchilds/qa/qa.pdf)

    the above does no not cover all we will do, and covers materials we will not do

    - second part of course: Hidary's "Quantum Computing: An Applied Approach "
    - online tutorials & lecture notes

- **You will need a laptop per person/small group for later tutorials**

Technicalities

- Where and when:
  Lectures: **Fridays 11:15-13:00, Huygens DeSitter/Gorlaeus 04/5 or 3**
  (see webpage http://liacs.leidenuniv.nl/~dunjkov/aQa.html for listing)
  Tutorials: **Fridays 16:15 - 18:00, SNELLIUS 403**

- (some of the) lectures will be recorded. You will not be visible on the recordings.

- Course will involve theory and applied work (programming), so both lectures and tutorials are important

Grading

- No exam.
- **50% grade 2 x take home assignments**
  - first problem sheet already available online
  - deadline for submission: 28th Feb (see web page http://liacs.leidenuniv.nl/~dunjkov/aQa.html)
- **50% grade 2 mini-projects** in the second half of course
  - report will be a jupyter notebook for each project
- THAs: you have mastered the basic theory;
- Mini-projects: topic-specific &
  you know how to apply it; (more demanding)

Curriculum

Crash course + certain advanced topics

1. Background: basics of computation, quantum mechanics, quantum circuits
2. Basics of quantum computing, quantum algorithms, complexity (includes advanced topics)

Algorithmic background

3. Simulating quantum physical systems: Hamiltonian simulation
4. Variational quantum circuits (VQE)
5. Quantum phase estimation algorithms and applications

Algorithms for strongly correlated systems and chemistry

6. Quantum algorithms for strongly correlated systems - overview
7. QAs for strongly correlated systems: spin Hamiltonians
8. QAs for strongly correlated systems: fermionic systems
9. QAs for strongly correlated systems: state preparation

Optimization and machine learning algorithms

10. (Tutorial lesson): From VQEs to Quantum approximate optimization
11. Quantum Machine Learning 1: Paramterized supervised learning
12. Quantum Machine Learning 2: generative models and beyond

Aspects of real-world quantum computing

13. Toward real-world quantum computing: quantum error correction and mitigation
14. Toward real-world quantum computing: state-of-the-art machinery
15. Machine learning for quantum information processing

Questions?