

A course in Quantum Computation Introduction

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UNITED NATIONS
UNIVERSITY

UNU-EGOV

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The subject

Alan Turing (1912 - 1934)



On Computable Numbers, with an Application to the Entscheidungsproblem (1936)

(computability and the birth of computer science)

The subject

Richard Feynman (1918 - 1988)



Simulating Physics with Computers (1982)
(quantum reality as a computational resource)

The subject

Davis Deutsch (1953)



Quantum theory, the Church-Turing principle and the universal quantum computer (1985)

(quantum computability and computational model:
first example of a quantum algorithm that is exponentially faster than
any possible deterministic classical one)

The subject

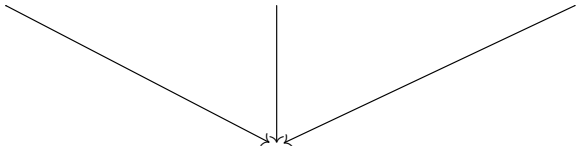
quantum resources



quantum algorithms



computability



The subject

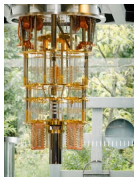
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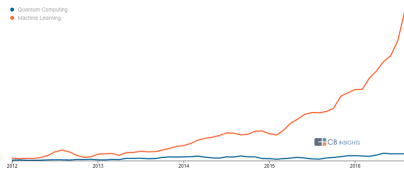
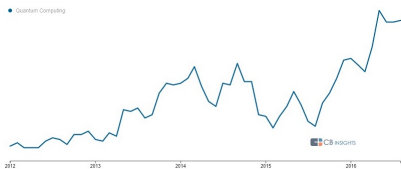
Quantum is trendy ...

The second quantum revolution

For the first time the viability of quantum computing may be **demonstrated in a number of real problems** extremely difficult to handle, if possible at all, classically, and **its utility discussed across industries**.

- **huge investment** by both the States, large companies and startups
- the **race for quantum** rising between major IT players (e.g. IBM, Intel, Google, Microsoft)
- **proof-of-concept machines** up to 50 qubits until the end of 2018
- **national and regional programmes** (from the 2016 Quantum Manifesto to the EU QT Flagship)

... but the race is just starting



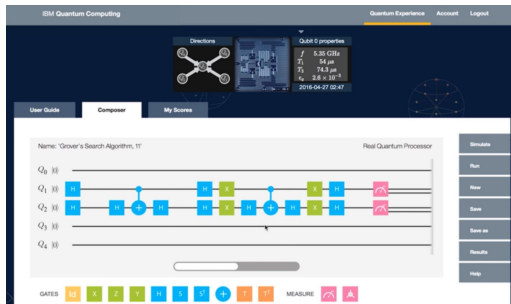
- Clearly, quantum computing will have a **substantial impact on societies** even if, being a so **radically different technology**,
- ... it is difficult to **anticipate its evolution** and future applications ...
- ... and its **commercial potential** in the near term (5 to 10 yrs) is still debatable

Where exactly do we stand?

Short term

Quantum advantage with **Noisy Intermediate-Scale Quantum (NISQ)**
Hybrid computational models:

- the quantum device as a coprocessor
- typically accessed as a service over the cloud



Where exactly do we stand?

Longer term

Fault tolerant quantum computing, based on error correction codes (using millions of physical qubits to implement a logic one)

From now to then there is a need for

- basic research (in several fronts), but also
- use cases
- capacity building
- process re-engineering
- anticipating social impacts and challenges

Learning Outcomes

On successful completion of the course students should be able

- To understand basic concepts of computability, computational complexity, and underlying mathematical structures;
- To master the quantum computational model;
- To design and analyse quantum algorithms;
- To implement and run quantum algorithms in the Qiskit open-source software development kit for IBM Q quantum processors.

Course Information and Pragmatics

Refer to the course website at

`arca.di.uminho.pt/quantum-computation-2021/`

Invitation to a fast running train ...

Academic IBM Q HUB since September, 1, 2018

- Part of the worldwide IBM Q Network of companies and academies to exploit potential applications of Quantum Computing in Industry
- Real time, full access to new quantum machines
- Multidisciplinary, dedicated teams
- A problem-driven research
- International cooperation



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