A course in Quantum Computation
Introduction

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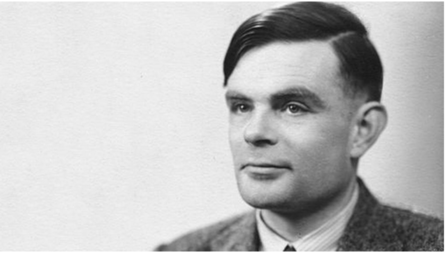
The subject

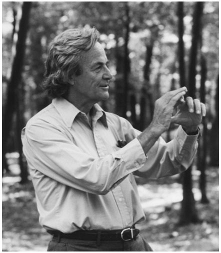
Alan Turing (1912 - 1934)



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)

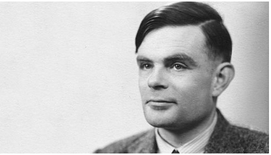
Quantum theory, the Church-Turing principle and the universal quantum computer (1985)
(quantum computability and computational model:
first example of a quantum algorithm that is exponentially faster than any possible deterministic classical one)

The subject

quantum resources

quantum algorithms

computability



The subject

quantum resources

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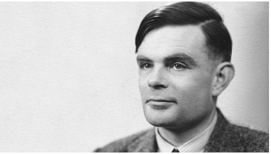
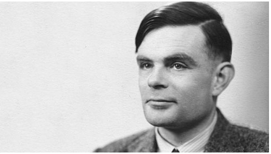


The subject

quantum resources

quantum algorithms

computability



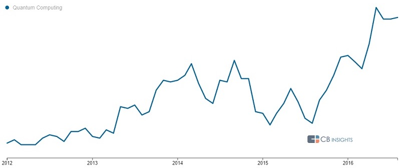
Quantum is trendy ...

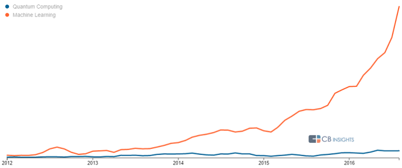
The second quantum revolution

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





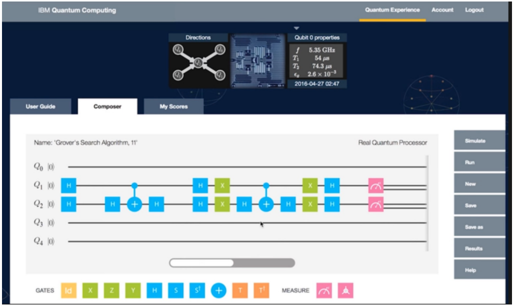
- Clearly, quantum computing will have a substantial impact on societies even if, being a so radically different technology,
- ... it is difficult to anticipate its evolution and future applications ...
- ... and its commercial potential in the near term (5 to 10 yrs) is still debatable

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, base 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 functional programming languages (Quipper) and the Qiskit development kit for IBM Q quantum processors.

Course Information and Pragmatics

Refer to the course website at

`arca.di.uminho.pt/quantum-computation-2122/`