

# PASQAL

## QUANTUM DISCOVERY

Simulation, optimization and machine learning

**PASQAL**

[www.pasqal.com](http://www.pasqal.com)

[office@pasqal.com](mailto:office@pasqal.com)

7 rue Léonard de Vinci

91300 Massy

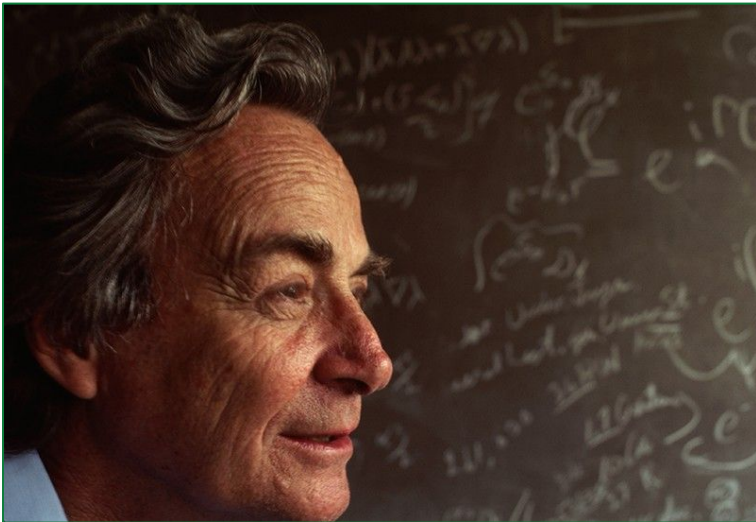
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# Simulation

## Simulation problem

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A simulation is the imitation of the operation of a real-world process or system over time. Simulating quantum phenomena is a very hard task for classical computers.

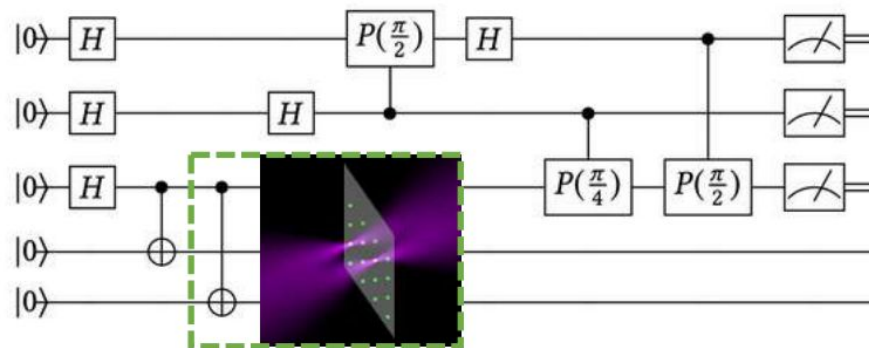


“Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy.” - **Richard Feynman**

# Simulation

## Analog vs Digital quantum simulation

(a) Digital processing



(b) Analog processing

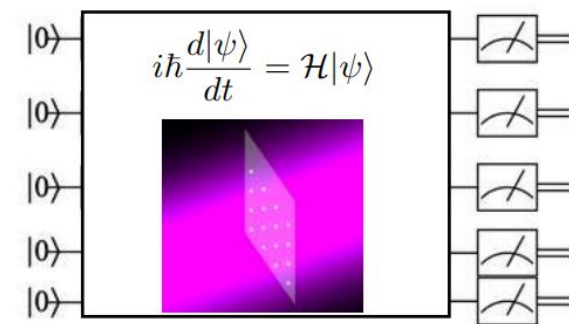


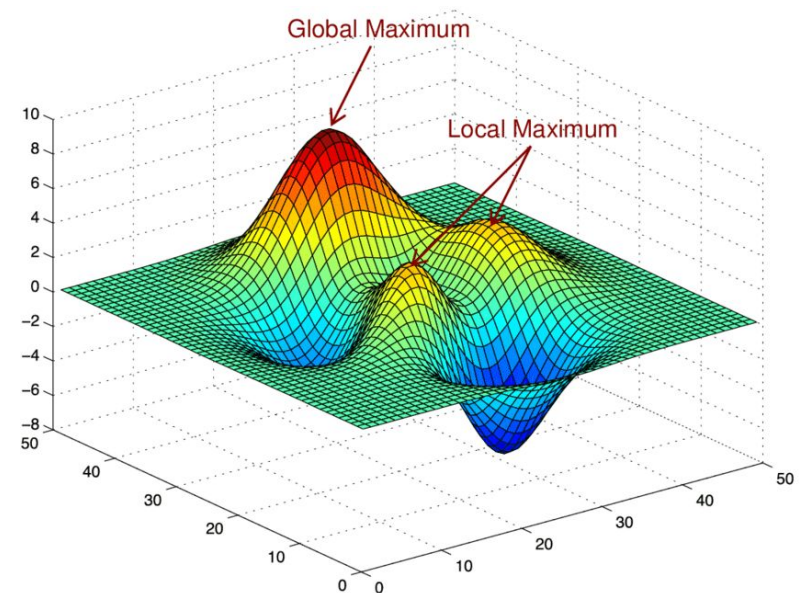
Figure 6: Digital- vs analog processing. (a) In digital processing, a succession of gates is applied to the qubits to implement a quantum algorithm. Each gate is performed by addressing the qubits individually with laser beams. (b) In analog processing the qubits evolve under a tailored Hamiltonian  $\mathcal{H}$ , for instance by illuminating the whole register with a laser beam. The wavefunction  $|\psi\rangle$  of the system follows the Schrödinger equation.

*Source: PASQAL*

# Optimization

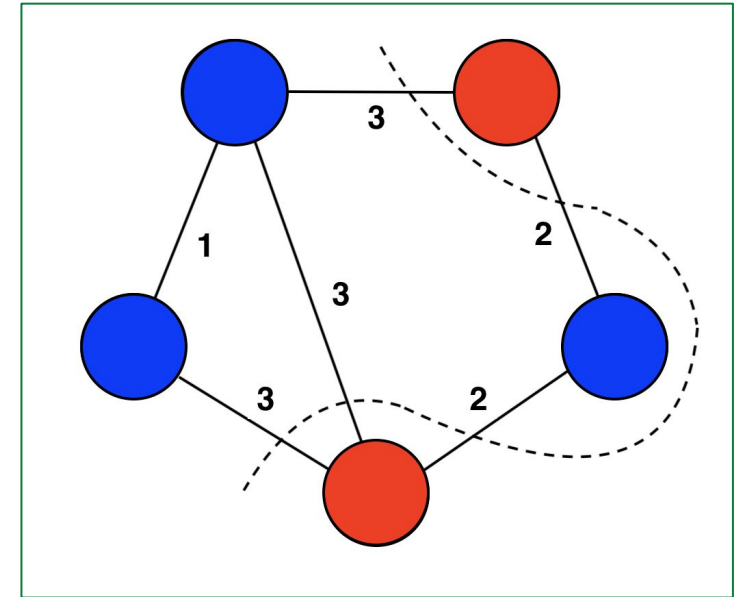
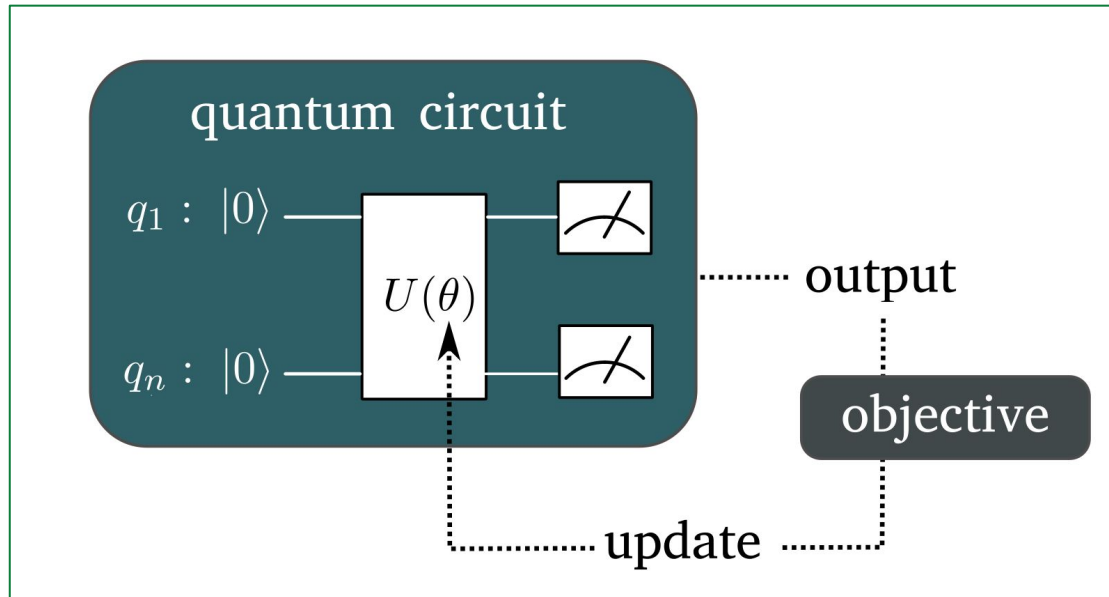
## Optimization problem

Finding the best solution with the least error from a multitude of possible solutions. Most optimization problems are formulated as minimization problems.



# Optimization

## Variational quantum algorithms



# Machine learning

## Machine learning problem

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Machine learning consists in extracting information from data and using it to predict trends and behaviour patterns.

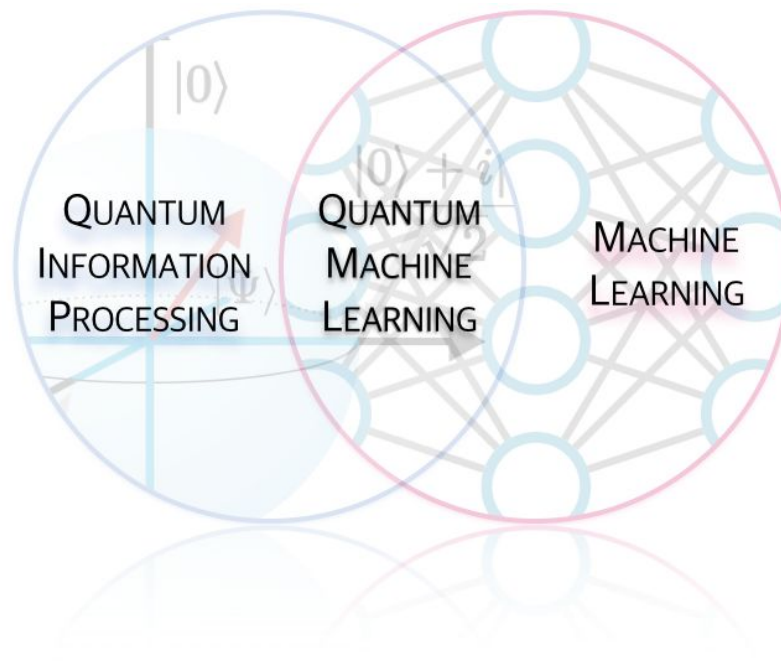
- **Supervised learning (i.e. classification / regression):** The machine learning task of learning a function that maps an input to an output based on example input-output pairs.
- **Unsupervised learning (i.e. clustering):** a type of machine learning that looks for previously undetected patterns in a data set with no pre-existing labels.



# Machine learning

## Quantum machine learning

Quantum machine learning is a new research field at the interplay of quantum computing and machine learning.



		Type of Algorithm	
		<i>classical</i>	<i>quantum</i>
Type of Data	<i>classical</i>	CC	CQ
	<i>quantum</i>	QC	QQ

# Conclusion

- Quantum computing can deliver immense benefits in three areas: simulation, optimization, and machine learning
- Quantum simulation can be either digital or analog, depending on the problem formulation and the available quantum hardware
- Combinatorial optimization problem are well suited for solving on a quantum computer.
- Quantum machine learning is a new research field at the interplay of quantum computing and machine learning.