Quantum Computing & Quantum Machine Learning tutorials

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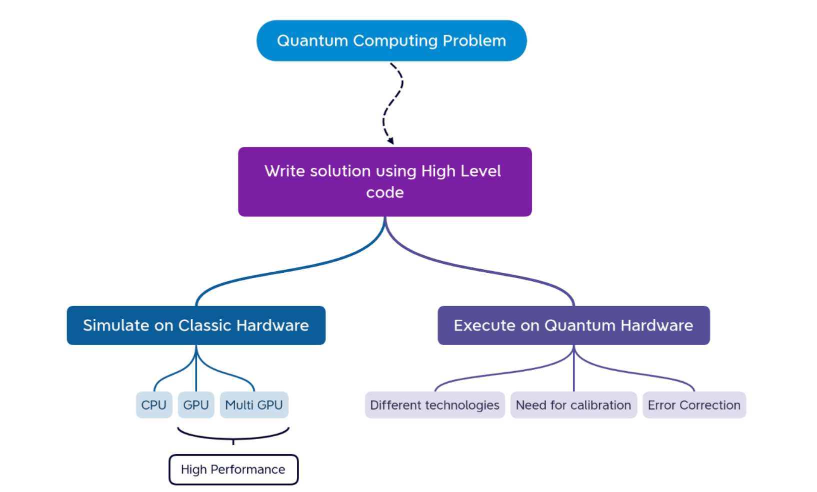
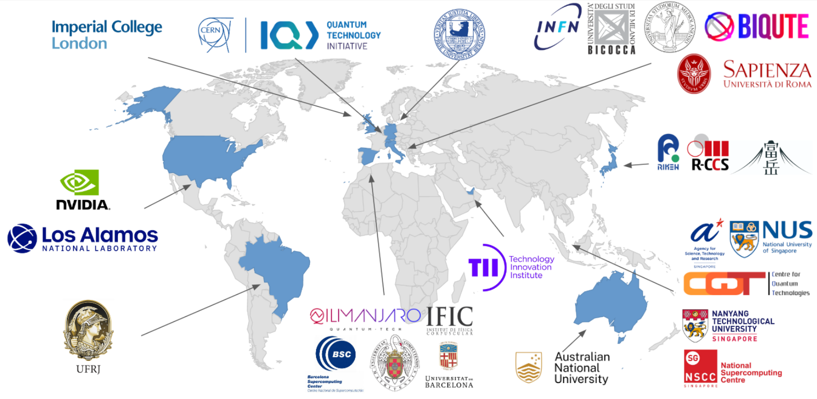
July, 2023

Quantum Computing using `Qibo`

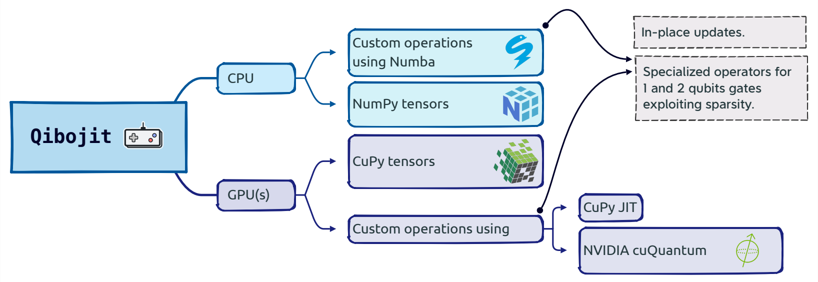
The aim of `Qibo`



Contributors at July 2023



High performance quantum simulation



Quantum simulation with just-in-time compilation, 2022

Quantum Machine Learning

Variational Quantum Circuits (VQCs)

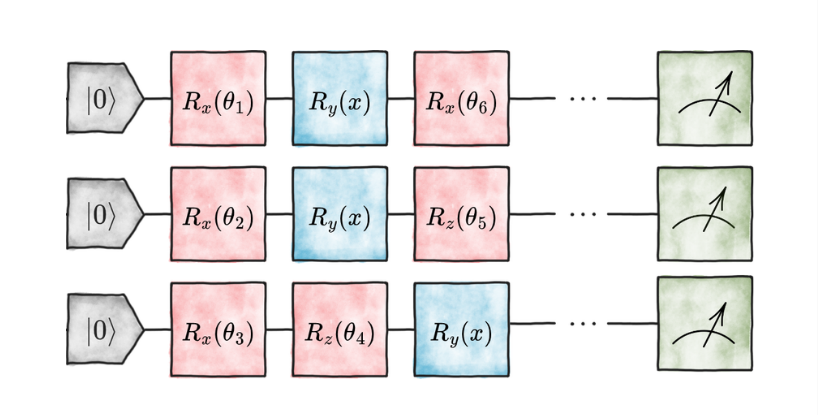


Figure 1: `AKA` a circuit with some parameters, which we call $\mathcal{U}(\boldsymbol{\theta})$.

Quantum Machine Learning - doing ML using QC

Machine Learning
$\mathcal{M}$: model;
$\mathcal{O}$: optimizer;
$\mathcal{J}$: loss function.
(x, y): data

Quantum Computation
$\mathcal{Q}$: qubits;
$\mathcal{S}$: superposition;
$\mathcal{E}$: entanglement.

Quantum Machine Learning - operating on qubits

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VQC execution
$\mathcal{M}$, $\mathcal{S}$, $\mathcal{E}$
$\mathcal{U}(\boldsymbol{\theta})\,|q_i\rangle \rightarrow |q_f\rangle$

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$y_{est} \equiv \langle q_f|B|q_f\rangle$

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Quantum Machine Learning!

Optimizer $\mathcal{O}$
Hybrid-strategy

Machine Learning
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loss function $\mathcal{J}$
$\mathcal{J}(y_{meas}, y_{est})$

Expected values
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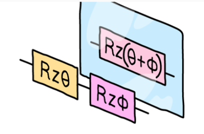

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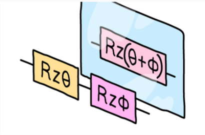
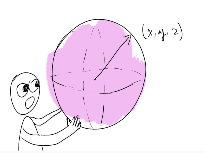
- map problems into Hilbert's spaces loads to high **expressivity**;





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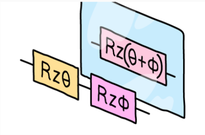
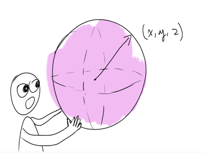
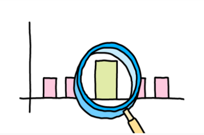
- exploit QC sub-routines to **speed-up** classical algorithms (e.g. using Grover);

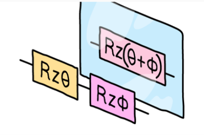


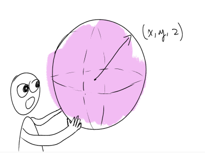


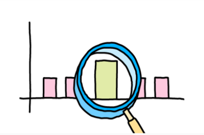
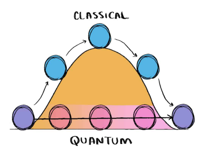


Why QML?

- **shallow models** thanks to superposition and entanglement;
- map problems into Hilbert's spaces loads to high **expressivity**;
- exploit QC sub-routines to **speed-up** classical algorithms (e.g. using Grover);
- physical advantages when dealing with **combinatorial optimization** (quantum annealing).





Rational

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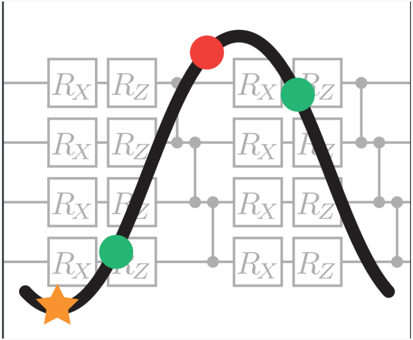

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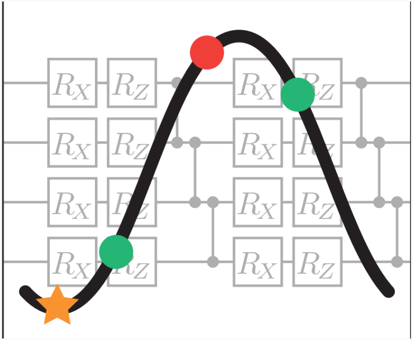

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1. we want a quantum circuit $\mathcal{U}(\boldsymbol{\theta})$ to approximates some law V;
2. executing $\mathcal{U}(\boldsymbol{\theta})$ we use a variational quantum state to reach the solution;
3. **Solovay-Kitaev theorem**: the number of gates needed by $\mathcal{U}$ to represent V with precision δ is $\mathcal{O}(\log^c \delta^{-1})$, where $c < 4$.