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LIRMM TotalEnergies CERFACS

EUROPEAN CENTRE FOR RESEARCH AND ADVANCED TRAINING IN SCIENTIFIC COMPUTING

Implementation of a quantum BLAS library

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Solving PDEs with Quantum Computing

Problem of interest

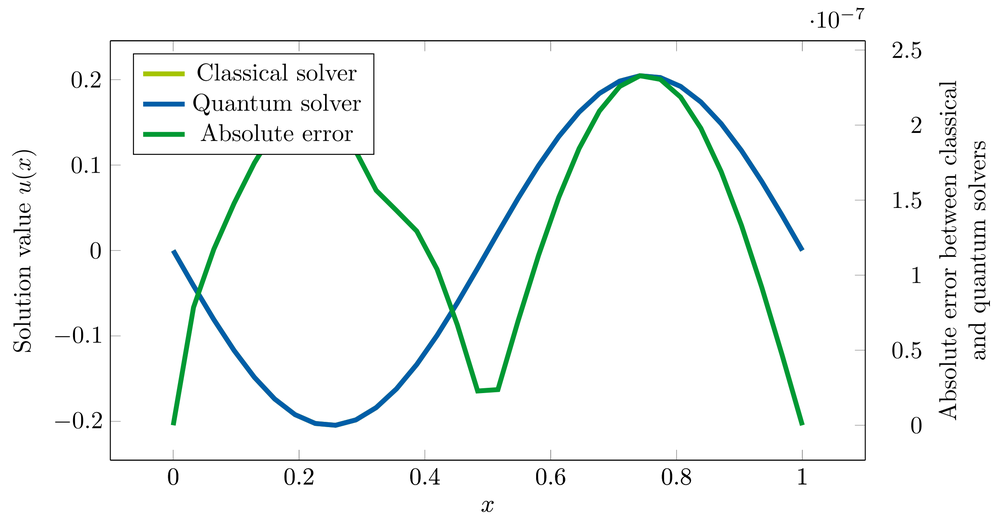
Can we use a quantum computer to solve real problems like PDEs or linear systems?
For example the wave equation with Dirichlet boundary conditions

$$\frac{\partial^2 u}{\partial t^2} = c\Delta u, \qquad \frac{\partial u}{\partial x}(0,t) = \frac{\partial u}{\partial x}(1,t) = 0$$

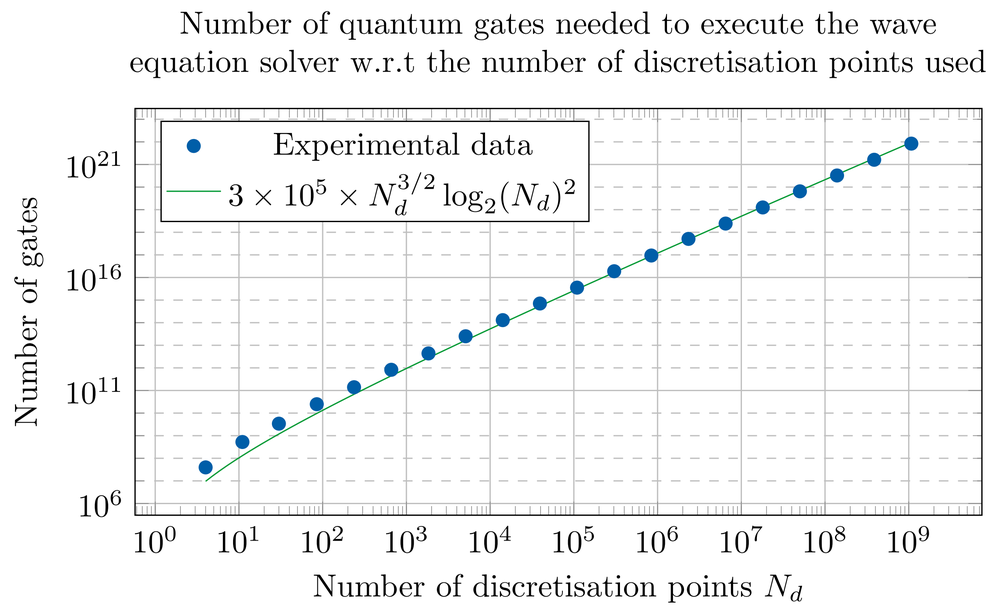
And if it is possible, does it works? Is it efficient? What core algorithms do we need?

Implementation of a quantum wave equation solver

Comparison of the results obtained by our quantum solver with a classical finite-differences solver on a simple use-case.



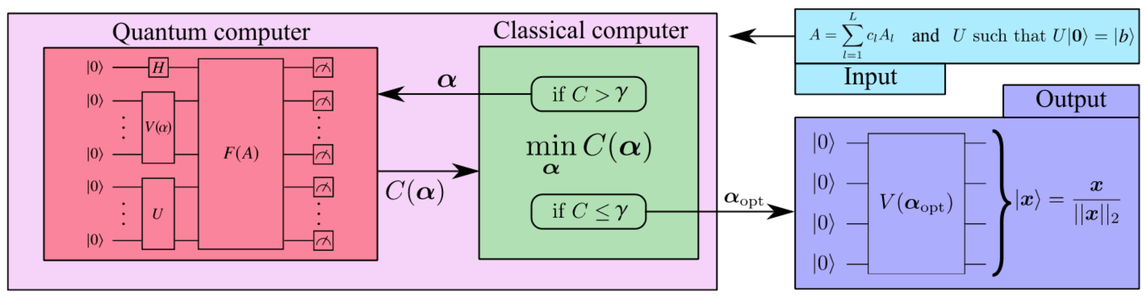
With the following resources requirements:



Adrien Suau, Gabriel Staffelbach, and Henri Calandra. 2021. Practical Quantum Computing: Solving the Wave Equation Using a Quantum Approach. ACM Transactions on Quantum Computing 2, 1, Article 2 (April 2021), 35 pages. doi: 10.1145/3430030

Variational Quantum Linear Solver (VQLS)

"Direct" algorithms are not suitable for current hardware (too much gates w.r.t noise).
Idea: use a variational algorithm to run on real hardware

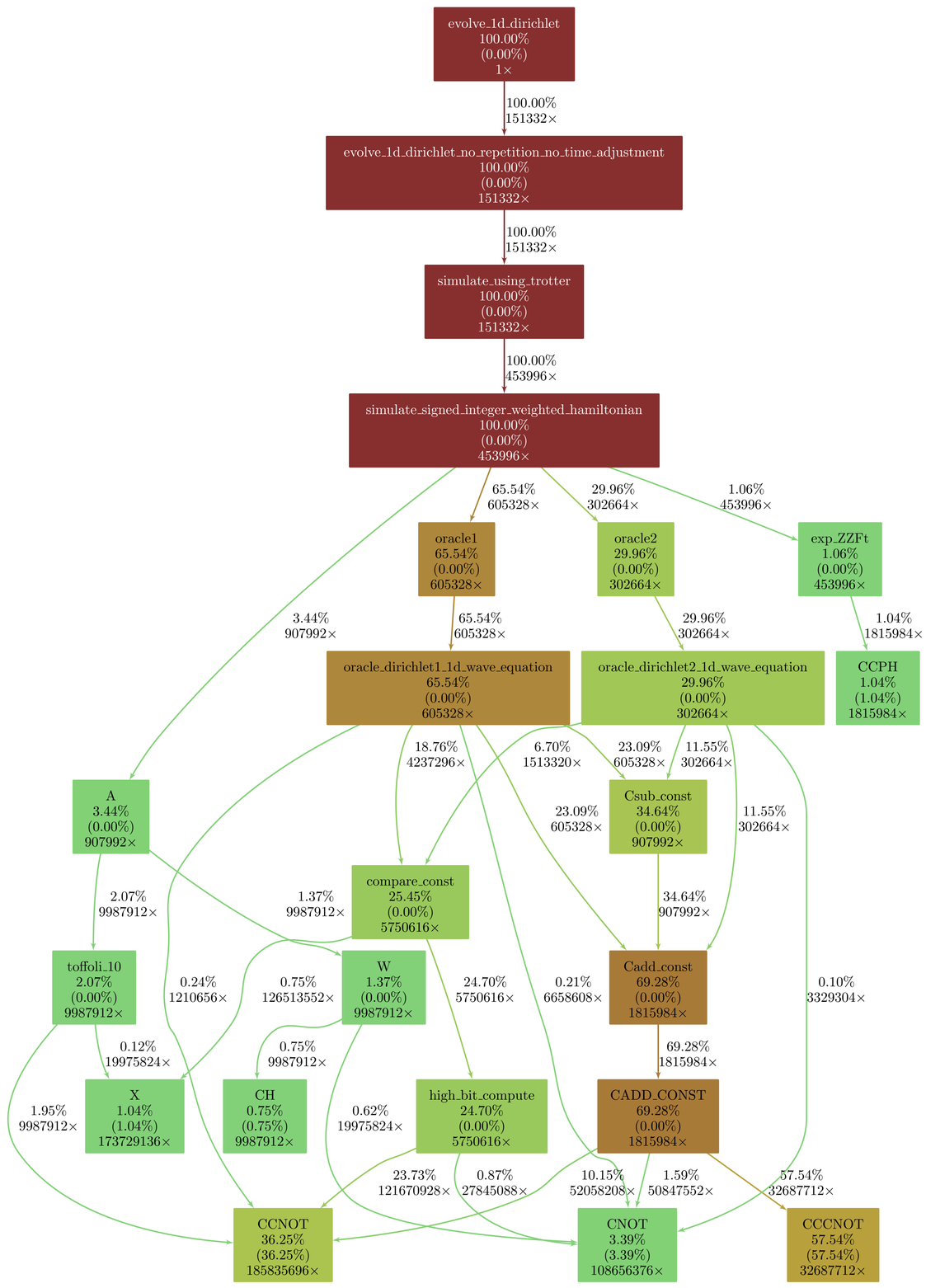


Bravo-Prieto, C., LaRose, R., Cerezo, M., Subasi, Y., Cincio, L., and Coles, P. J., "Variational Quantum Linear Solver", arXiv:1909.05820, 2019.

Tools for Quantum Computing

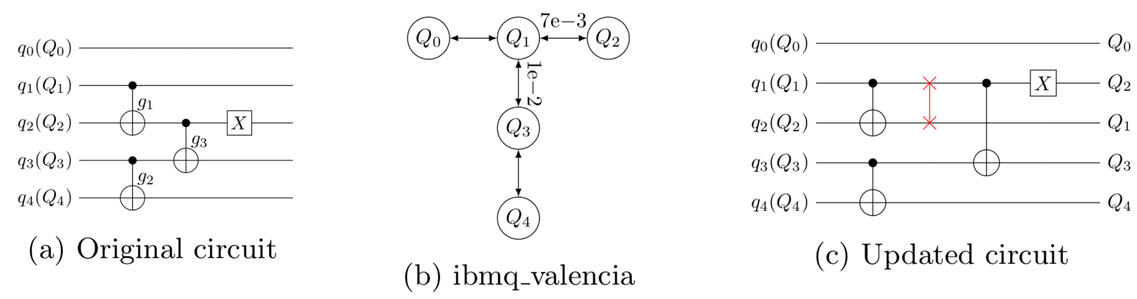
`qprof` quantum profiler

How to optimise efficiently quantum programs implementation?
No profiler yet, so we created one.



Qubit mapping

Hardware-aware compiler: takes an abstract quantum circuit and adapt it to the hardware characteristics. Use noise data extracted from calibrations to improve the overall fidelity.



(a) Original circuit (b) ibmq_valencia (c) Updated circuit

S. Niu, A. Suau, G. Staffelbach and A. Todri-Sanial, "A Hardware-Aware Heuristic for the Qubit Mapping Problem in the NISQ Era" in IEEE Transactions on Quantum Engineering, vol. 1, pp. 1-14, 2020, Art no. 3101614, doi: 10.1109/TQE.2020.3026544.