Quantum Metropolis Solver (QMS): A Quantum Walks Approach to Optimization Problems

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BACKGROUND

The efficient resolution of optimization problems is one of the key issues in today's industry. This task relies mainly on classical algorithms that present scalability problems and processing limitations. Quantum computing has emerged to challenge these types of problems. Quantum Metropolis-Hastings algorithm, based on quantum walks, allows us to build a quantum software tool called Quantum Metropolis Solver (QMS).

We validate QMS with the protein folding problem [2] and Gravitational Waves parameter estimation [3] to show a potential quantum advantage in an example that can be easily extrapolated to an Artificial Intelligence domain. We carry out different simulations to validate the performance of QMS and its configuration.

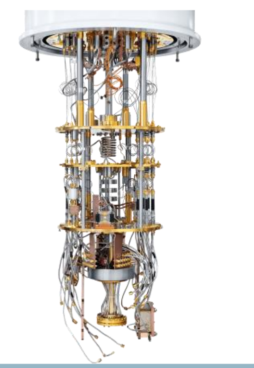
START HERE

JUSTIFICATION

Current classical optimization algorithms face a significant scalability hurdle — when tackling more intricate problems, the algorithms demand years to generate a satisfactory solution. Quantum computing emerges as a promising remedy to this scalability challenge. Previously, quantum computers were limited by encoding and solving optimization problems within quantum circuits. We develop QMS, a quantum software based on quantum walks [1] capable of resolving optimization problems that adhere to specific criteria. QMS is a software implementation, enabling execution on both quantum simulators and actual quantum computers.

Quantum simulator | Quantum computer

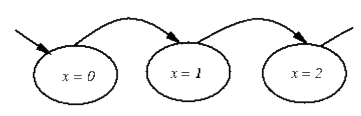
Qiskit



Sample a function

$$W = RV^\dagger B^\dagger FBV$$

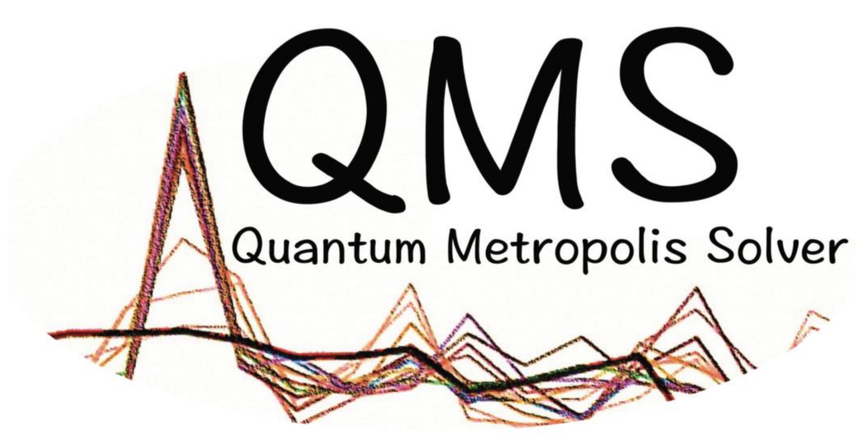
States

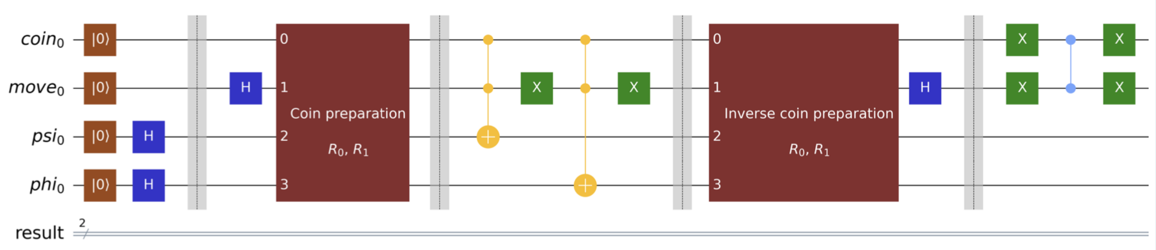


$$|s> = \left\{\sum_{x\in\mathbb{N}} \alpha_x |x>\right\} \epsilon\, \mathcal{H}_s$$

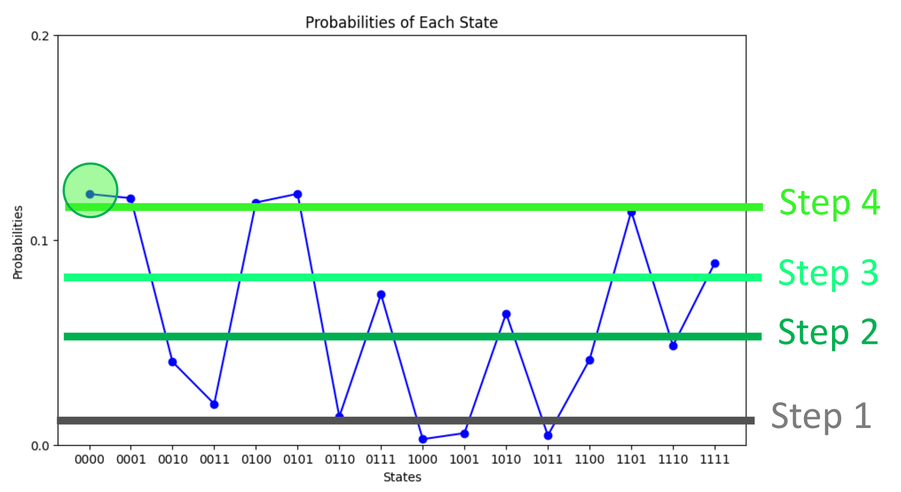
Coin

$$|c> = \{\alpha_1|\uparrow> + \alpha_2|\downarrow>\} \epsilon\, \mathcal{H}_c$$

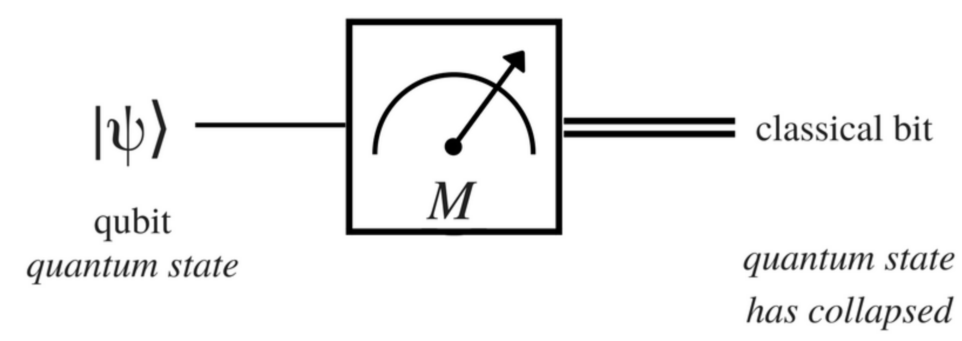




Search maximum



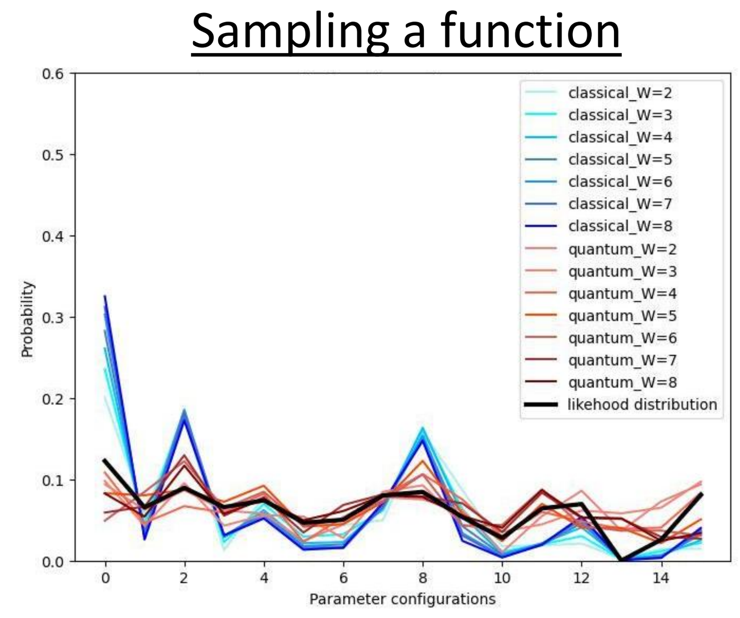
Measure the circuit



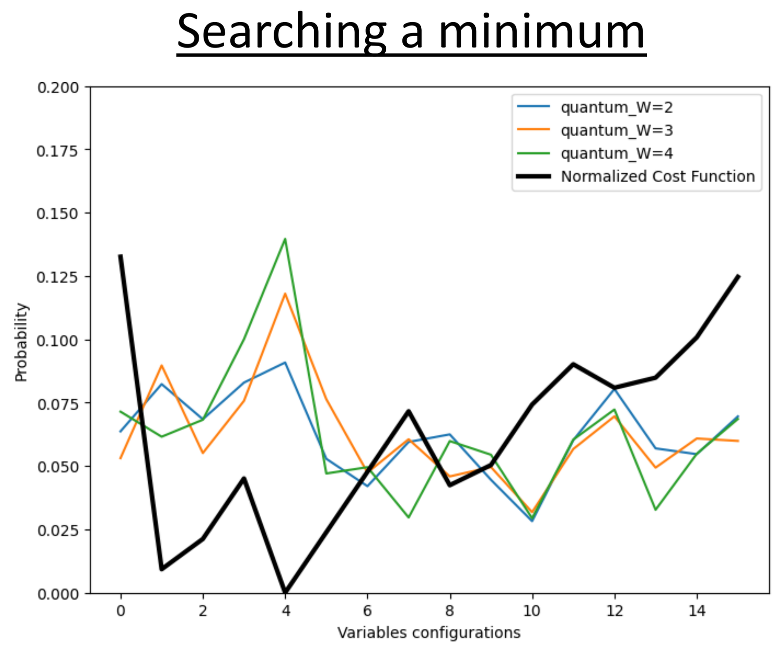
RESULTS

Optimization problems

Sampling a function

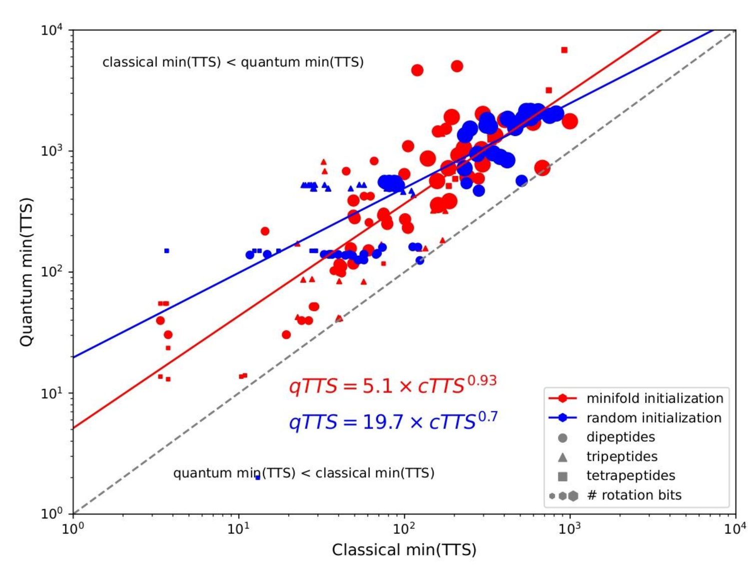


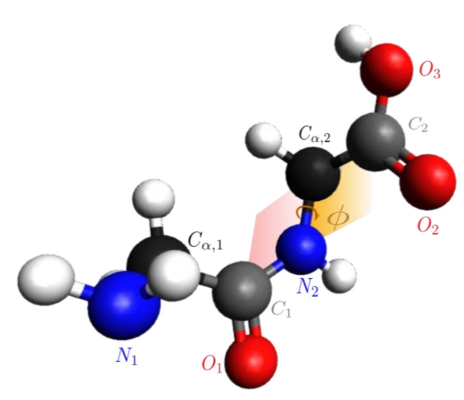
Searching a minimum



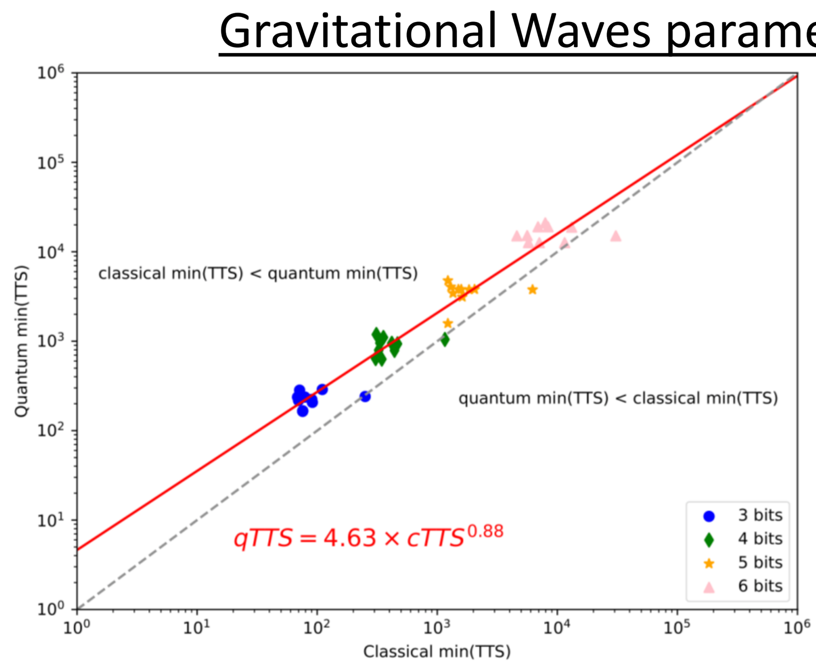
Real World Problems

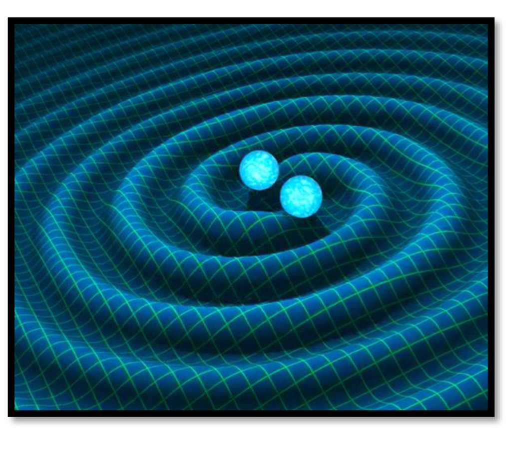
Protein Folding



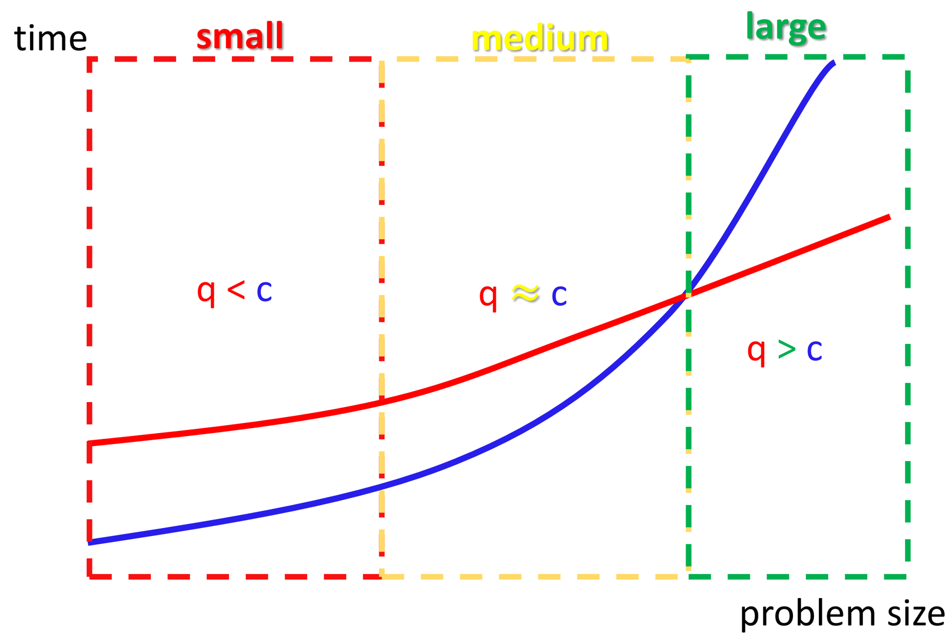


Gravitational Waves parameter estimation





Scalability



Problem size (number of states)	Qubits	RAM Memory
2^{21} = 2.097.152	33	32GB
2^{22} = 4.194.304	34	64GB
2^{23} = 8.388.608	35	128GB
2^{23} = 8.388.608	36	256GB
2^{24} = 16.777.216	37	512GB

[1] A. Galindo and M. A. Martin-Delgado, "Family of grover's quantum-searching algorithms," Physical Review A, vol. 62, no. 6, p. 062303, 2000.
[2] P A M Casares, R Campos, M A Martin-Delgado, "Qfold: Quantum Walks and Deep Learning to Solve Protein Folding," in Quantum Science and Technology, vol. 7.
[3] G Escrig, R Campos, PAM Casares, MA Martin-Delgado, "Parameter estimation of gravitational waves with a quantum metropolis algorithm," Classical and Quantum Gravity, vol. 4.

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