Nonlinear dynamics as a ground-state solution on quantum computers

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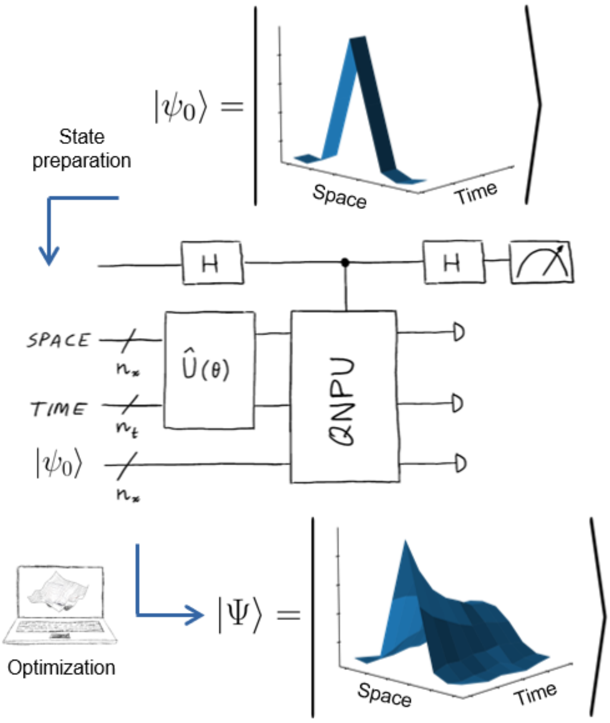
In this talk, we describe how variational quantum algorithms (VQAs) can be used to solve nonlinear partial differential equations (PDEs) with applications in battery or semiconductor research, as well as other engineering problems [1]. VQAs are hybrid quantum-classical algorithms, where a cost function is calculated on a quantum computer and its parameters are optimised classically. We present a spacetime representation, inspired by the Feynman–Kitaev Hamiltonian [2], where the solution to a PDE at all times is obtained by minimising just one function.



We describe how quantum nonlinear processing units [3] can be used to evaluate the required cost function efficiently. We propose an adaptive strategy to mitigate the barren plateau problem, which means that gradients vanish exponentially with the number of qubits.

The approach is illustrated for the nonlinear Burgers equation. We optimise the problem on a noiseless simulator and run the circuits containing the result on IBM Q System One and Quantinuum Model H1, demonstrating that current quantum computers are capable of accurately reproducing the exact results.

[1] Pool, A.J. et al. arXiv:2403.16791
[2] Barison, S. et al. Phys. Rev. Res. 4 (2022), 043161
[3] Lubasch, M. et al. Phys. Rev. A 101 (2020), 010301(R)