Maximizing Quantum Fisher Information with Physics-Informed Neural Networks

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Abstract

We present a physics-informed neural-network framework to maximize quantum Fisher information (QFI) in time-dependent many-body Hamiltonians. The model learns the coefficients of the adiabatic gauge potential in a Pauli-string basis together with a trainable schedule λ(t), while the loss enforces the minimum-action Euler-Lagrange equation, penalizes non-commutativity, and drives the final state toward the extremal-eigenstate superposition associated with the QFI optimum. To reduce the cost of sequential propagation, the dynamics are approximated with a windowed third-order Magnus expansion. We benchmark nearest-neighbor, dipolar, and trapped-ion spin Hamiltonians for q = 2-6 qubits. For the largest systems, the learned protocols reach normalized efficiencies η_QFI ≈ 0.98, with final-state fidelity and extremal-balance scores close to 0.99, while the Euler-Lagrange residual remains in the 10^-5-10^-4 range in the best regimes. Inference remains sub-millisecond per forward pass, showing that physics-constrained PINNs are a promising route for metrologically optimal control in non-commuting quantum dynamics.

References

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[3] D. Pang and A. N. Jordan, Nat. Commun. 8 (2017) 14695.

Figures

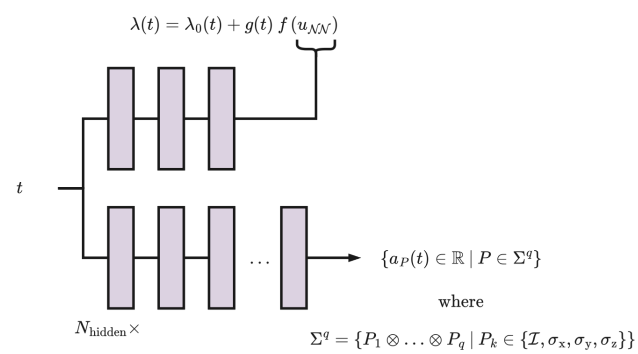

Figure 1: PINN architecture used to infer the adiabatic gauge potential coefficients and the trainable scheduling function λ(t).

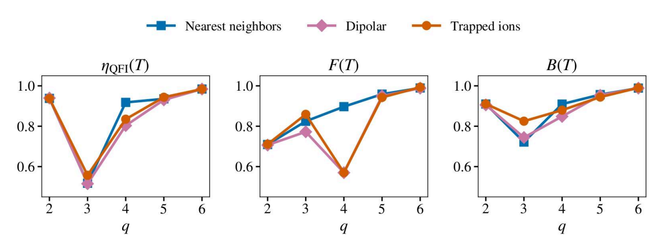

Figure 2: Evaluation metrics versus qubit count q for the different Hamiltonians considered. Columns report normalized QFI, final fidelity F, and final extremal-eigenstate balance B, all measured at $t = T$, with the Hamiltonians overlaid in each panel.