Machine Learning Methods for Quantum Thermal Devices

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In the past few years, Machine Learning (ML) applications in the field of quantum physics and quantum technologies have surged along various directions. For instance, ML has been used for quantum state tomography, quantum state representation, to approximate quantum dynamics, and to design quantum optics experiments [1].

In this presentation, we focus on ML methods for the optimal control and optimal design of quantum devices in the field of quantum thermodynamics, which has been much less explored.

First, we discuss how Reinforcement Learning provides a flexible framework for a variety of optimal control problems in non-equilibrium quantum thermodynamics [2]. After reviewing the general framework, we showcase its flexibility optimizing the power [3,4] and finding Pareto-optimal trade-offs between power, efficiency, and power fluctuations [5] of quantum thermal machines. We then show how the charging power and ergotropy of a quantum battery, exhibiting a collective speedup of the charging power, can be optimized [6]. In all cases, such an approach discovers novel control strategies that outperform previous proposals made in literature.

We conclude discussing how tools from machine-learning, namely gradient-based optimization methods, can lead to the optimal design of quantum devices for quantum thermodynamics, such as the discovery of optimal thermometers using spin networks [7].

[1] M. Krenn, J. Landgraf, T. Foesel, and F. Marquardt, Phys. Rev. A **107**, 010101 (2023).
[2] P. Sgroi, G. Massimo Palma, and M. Paternostro, Phys. Rev. Lett. **126**, 020601 (2021).
[3] P.A. Erdman and F. Noé, NPJ Quantum Inf. **8**, 1 (2022).
[4] P.A. Erdman and F. Noé, PNAS Nexus **2**, pgad248 (2023).
[5] P.A. Erdman, A. Rolandi, P. Abiuso, M. Perarnau-Llobet, and F. Noé, Phys. Rev. Res. **5**, L022017 (2023).
[6] P.A. Erdman, G. M. Andolina, V. Giovannetti, and F. Noé, arXiv:2212.12397 (2023).
[7] P. Abiuso, P.A. Erdman, M. Ronen, F. Noé, G. Haack, and M. Perarnau-Llobet, arXiv:2211.01934 (2022).