Machine learning-based device-independent certification of quantum networks

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Abstract

Detecting non-classical behaviors is a pivotal ingredient in several quantum technology tasks. The most widely employed techniques to verify the quantum features of a given physical device involve semi-definite programming [1]. However, such tools can only be applied to linear objective functions and constraints and become computationally unfeasible when the complexity and size of the system grow. Building on previous works [2], we introduce a strategy based on artificial neural networks, that allows to carry out numerical optimizations over supersets of the quantum set arising in arbitrary quantum networks. This method has two main advantages: firstly, it can be applied to nonlinear optimization constraints and objective functions, thus being suitable for scenarios featuring independent sources and nonlinear entanglement witnesses. Secondly, it requires less resources than other approaches, thus allowing to explore previously inaccessible regimes. We tested it on experimental data, obtaining estimates on Bell-like violations arising in scenarios involving independent sources of entangled photon states. This work may open new possibilities in the field of the certification of quantum resources in networks of arbitrary size and complexity.

References

[1] M. Navascués, S. Pironio, and A. Acín, "Bounding the set of quantum correlations," Phys. Rev. Lett., vol. 98, p. 010401, 2007.
[2] T. Kriváchy, Y. Cai, J. Bowles, D. Cavalcanti, and N. Brunner, "High-speed batch processing of semidefinite programs with feed-forward neural networks," New Journal of Physics, vol. 23, no. 10, p. 103034, 2021.

Figures

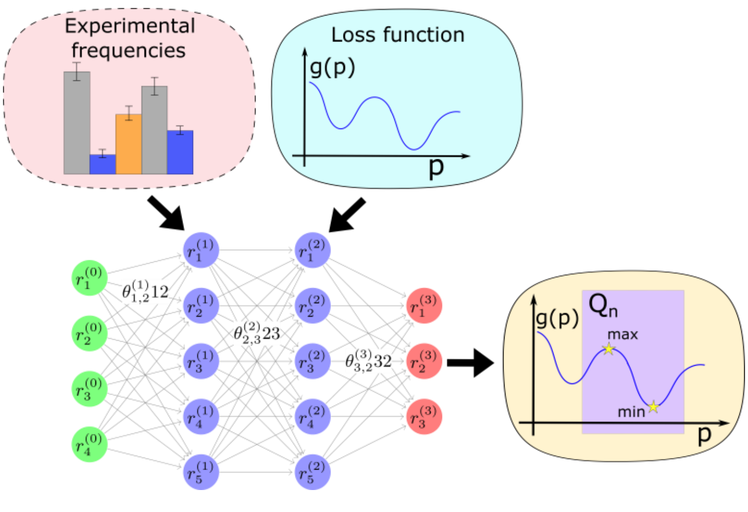

Figure 1: In the most general case, our optimizer takes as input a generic nonlinear function g(p) to be optimized over a given superset of quantum correlations Q_n and additional arbitrary constraints, eventually compatibly with experimental observations.