Efficient Quantum Tomography of Continuous Variable Quantum States

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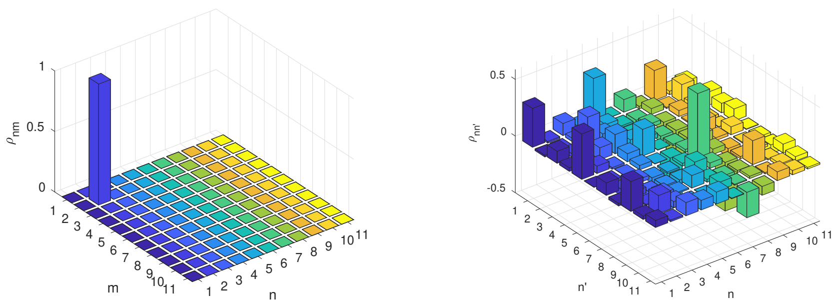
Abstract

We introduce an efficient method to reconstruct the Wigner function [1] of many-mode continuous variable systems. It is based on convex optimization with semidefinite programs (SDPs) [2], and also includes a version of the maximum entropy principle [3], in order to yield unbiased states.

A key ingredient of the proposed approach is the representation of the state in a truncated Fock basis. Though we are dealing with CV states and infinite dimensional Hilbert spaces, notice that the computations are always performed with a finite dimensional representation. The usual back-projection algorithm based on Inverse Radon Transform (IRT) [4], a well known algorithm for image reconstruction [5], is not viable for the multi-mode scenario once it demands high computational coast and it has difficult adjustments for many modes functions. Our SDP method delivers better results, demanding less measurements. In Figure 1, we can see an example of the density matrix reconstructed with the two methods.

As a bonus, the discrete finite representation allows to easily quantify the entanglement by partially transposing the state and calculating the Negativity [6].

Keynotes: Quantum Tomography, Continuous Variable State, Semidefinite Program



(a) (b)

Figure 1: The density matrix of Fock state $|1\rangle$ reconstructed via (a) SDP, and (b) Inverse Radon Transform (IRT). Notice that the IRT reconstruction resulted in negative values in the diagonal, *i.e*, an non-physical state.

References

[1] E. P. Wigner, "On the quantum correction for thermodynamic equilibrium", Phys. Rev. 40, 749 (1932).

[2] T. O. Maciel, A. T. Cesário, and R. O. Vianna, "Variational quantum tomography with incomplete information by means of semidefinite programs", Int. J. Mod. Phys. C 22, 1361 (2011).

[3] D. S. Gonçalves, C. Lavor, M. A. Gomes-Ruggiero, A. T. Cesário, R. O. Vianna, and T. O. Maciel, "Quantum state tomography with incomplete data: Maximum entropy and variational quantum tomography", Phys. Rev. A 87, 052140 (2013).

Quantum Process Tomography", Quantum Inf. Comput. 12, 0442 (2012)

[4] J. Betrand, and P. Bertrand, "A tomographic approach to Wigner's function", Found. Phys. 17, 397 (1987).

[5] G. Herman, "Image Reconstruction from Projections: The Fundamentals of Computational Tomography", Computer Science and Applied Mathematics Series, Academic Press (1980).

[6] G. Vidal, and R. F. Werner, "Computable measure of entanglement", Phys. Rev. A 65, 032314 (2002).