Detecting non-Gaussian entanglement using neural networks

Mathieu ISOARD

CNRS Sorbonne Université, LKB

isoard.mathieu@gmail.com

Entanglement and non-Gaussianity are physical resources essential for a large number of quantum optics protocols [2, 1]. However, detecting entanglement of non-Gaussian states is in general highly demanding and requires the reconstruction of the density matrix from experimental data.

In this talk, we discuss a machine learning protocol to detect entangled non-Gaussian states based on homodyne data; homodyne measurements are used in quantum optics to recover the statistics of the quadratures $\hat{q}$ and $\hat{p}$ and infer some properties, such as Wigner negativity [3]. Here, even from a very limited set of data, the neural network is able to find correlation patterns in the statistics to detect if the state is entangled or not. This is a huge improvement compared to usual methods based on the reconstruction of the density matrix, which requires a large set of homodyne data to converge.

The ability of the neural network to witness correlations from input data can be visualized in Fig. 1; this figure is obtained from a t-SNE algorithm, i.e., a dimension reduction technique for data visualization, before (a) and after (b) the neural network has processed input data. Each dot represents a quantum state; light blue dots are entangled states, while dark blue dots are separable states. One clearly sees from Fig. 1(b) that the network successfully clustered similar data (entangled or not) together.

Using machine learning as a tool to detect correlation patterns in experimentally accessible data is a very promising route towards the possibility to detect states that are not passively separable, i.e., the fact that the entanglement of a state cannot be undone with passive transformations (beamsplitters, phase shifters), a strong feature of non-Gaussian states necessary to reach a quantum computational advantage [1].

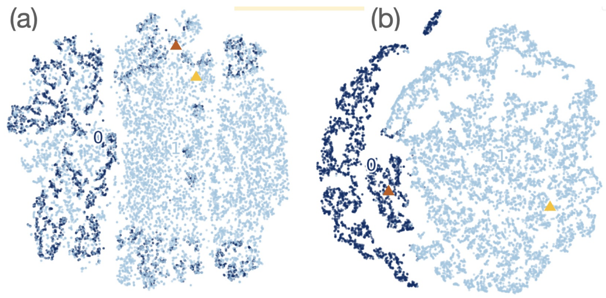

Figure 1: Clustering of similar data (entangled or not) (a) before or (b) after the neural network has processed input data. Each dot represents a quantum state.

References

[1] U. Chabaud and M. Walschaers. Resources for bosonic quantum computational advantage. *Phys. Rev. Lett.*, 130:090602, Mar 2023.

[2] A. Mari and J. Eisert. Positive wigner functions render classical simulation of quantum computation efficient. *Phys. Rev. Lett.*, 109:230503, Dec 2012.

[3] Y.-S. Ra, A. Dufour, M. Walschaers, C. Jacquard, T. Michel, C. Fabre, and N. Treps. Non-gaussian quantum states of a multimode light field. *Nature Physics*, 16(2):144–147, Feb 2020.