Classification and Reconstruction of Optical Quantum States with Deep Neural Networks

F Nori[1,2]

[1] *Physics, University of Michigan, Ann Arbor MI, USA*
[2] *Quantum Computing Center, RIKEN, Wako, Japan*
Contact Email: fnori@riken.jp

We apply deep-neural-network-based techniques to quantum state classification and reconstruction. Our methods demonstrate high classification accuracies and reconstruction fidelities, even in the presence of noise and with little data.

Using optical quantum states as examples, we first demonstrate how convolutional neural networks (CNNs) can successfully classify several types of states distorted by, *e.g.*, additive Gaussian noise or photon loss.

We further show that a CNN trained on noisy inputs can learn to identify the most important regions in the data, which potentially can reduce the cost of tomography by guiding adaptive data collection.

Secondly, we demonstrate reconstruction of quantum-state density matrices using neural networks that incorporate quantum-physics knowledge.

The knowledge is implemented as custom neural-network layers that convert outputs from standard feed-forward neural networks to valid descriptions of quantum states. Any standard feed-forward neural-network architecture can be adapted for quantum state tomography (QST) with our method.

We present further demonstrations of our proposed QST technique with conditional generative adversarial networks (QST-CGAN) [1,2]. We motivate our choice of a learnable loss function within an adversarial framework by demonstrating that the QST-CGAN outperforms, across a range of scenarios, generative networks trained with standard loss functions.

For pure states with additive or convolutional Gaussian noise, the QST-CGAN is able to adapt to the noise and reconstruct the underlying state. The QST-CGAN reconstructs states using up to two orders of magnitude fewer iterative steps than iterative and accelerated projected-gradient-based maximum-likelihood estimation (MLE) methods.

We also demonstrate that the QST-CGAN can reconstruct both pure and mixed states from two orders of magnitude fewer randomly chosen data points than these MLE methods.

Our paper opens possibilities to use state-of-the-art deep-learning methods for quantum state classification and reconstruction under various types of noise.

References

[1] S Ahmed, C S Munoz, F Nori and A.F. Kockum, Phys. Rev. Lett. **127**, 140502 (2021)

[2] S Ahmed, C S Munoz, F Nori and A F Kockum, Phys. Rev. Res. **3**, 033278 (2021)