Quantum state and process tomography of reduced data sets via a feed-forward neural network

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Quantum state tomography (QST) and quantum process tomography (QPT) are essential techniques to characterize quantum states and processes, and to evaluate the quality of quantum devices. There is hence a pressing need to develop more general and efficient methods for QST and QPT that are both experimentally and computationally efficient. Recently, machine learning (ML) techniques have been used to improve the efficiency of tomography protocols.[1] QST using an attention based generative network was realized experimentally on an IBMQ quantum computer.[2] Local measurement-based QST via ANN was experimentally demonstrated on NMR[3] and ML was used to detect experimental multipartite entanglement for NMR states.[4]

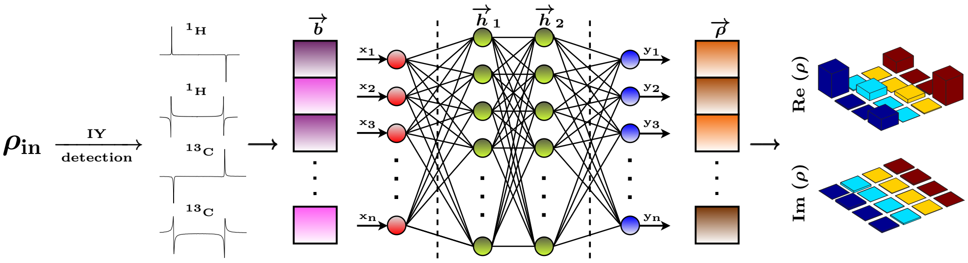

Figure 1: Schematic of an FFNN model with two hidden layers demonstrating the QST of a two-qubit quantum state; the set of NMR spectra are those obtained after the tomographic measurement.

In this work we used a feed-forward artificial neural network (FFNN) to perform QST and QPT of noisy experimental data. The FFNN performance was evaluated by using a heavily reduced data set and it was shown that the density and process matrices of unknown quantum states and processes can be reconstructed with high fidelity. The FFNN model was used to tomograph 100 two-qubit and 128 three-qubit states which were experimentally generated on a nuclear magnetic resonance (NMR) quantum processor as well to characterize different quantum processes including two-qubit entangling gates, a shaped pulsed field gradient, and intrinsic decoherence processes present in an NMR system. The results obtained via the FFNN model were compared with standard QST and QPT methods and the computed fidelities demonstrated that for all cases, the FFNN model outperformed the standard methods for tomography. These results have been published in Physical Review A (2024).[5]

References

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