Learning Complex States of 20 Qubit Ion Simulator

E S Tiunov[1,2], M Krishna K[3], V V Tiunova[4], A K Fedorov[5], and A I Lvovsky[2,6]

[1] *Department of General and Applied Physics, Moscow Institute of Physics and Technology, Dolgoprudny, Russia*
[2] *Laboratory for Quantum Optics, Russian Quantum Center, Moscow, Russia*
[3] *Physics and Astronomy, University of Calgary, Calgary, Canada*
[4] *Strongly correlated systems, Russian Quantum Center, Moscow, Russia*
[5] *Quantum Information Technologies, Russian Quantum Center, Moscow, Russia*
[6] *Department of Physics, Oxford University, Oxford, UK*
Contact Email: egor.tiunov@phystech.edu

The rapid development of quantum technologies inspires the creation of new methods to describe exponential large Hilbert spaces. Neural [1] and tensor network [2] Ansatzes are effective representations that are able to extract features of the quantum state from measurement data. In this work, measurements of the 20 qubit ion simulator are used to solve the quantum tomography problem [3]. We compare the performance of matrix product states (MPS) with the autoregressive network (ARN) and Restricted Boltzmann Machine (RBM). MPS is induced by the one-dimensional geometry of the physical system. At the same moment, neural networks are more general Ansatzes, and they can describe more complex states, for example, states with volume law entanglement scaling [4]. MPS results outperform neural networks in terms of likelihood on experimental data and terms of fidelity on artificial ones. The explanation for that is a geometry of the experimental setup, and the ion chain is a 1D system. In this case, the 1D tensor network is more suitable than any general Ansatz.

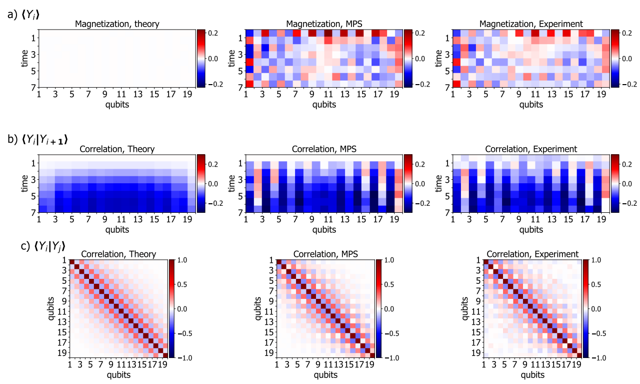

Figure 1: 20-qubit state reconstruction. For the observable σ_Y, a) single-qubit expectation values; b) correlations for neighboring qubits; c) full pairwise correlations are shown. The vertical axis in (a) and (b) enumerates the eight-time moments for which the measurements were made; the data in (c) correspond to moment 6 ($t = 3$ ms). The left columns show the data computed from the state reconstructed from the experimental data via MPS, the central column corresponds to the theoretically expected evolution, and the right column is obtained directly from the experimental data

Apart from a simple comparison, our results prove a more general statement. To the best of our knowledge, we, for the first time, fully characterize the 20 qubit quantum setup on highly incomplete sets of measurements. Each set corresponds to the concrete moment of the quantum evolution starting for the Nèel state. In the abstract, we present different observables calculated from reconstructions, theory, and directly from the data (1). We see that the agreement between the reconstructed state and the data is much better than that between either of the two and the theoretical model.

References

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