Predicting three-dimensional Chaotic Systems with Four Qubit Quantum Systems

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Reservoir computing (RC) is among the most promising approaches for AI-based prediction models of complex systems. It combines superior prediction performance with very low CPU-needs for training. Recent results demonstrated that quantum systems are also well-suited as reservoirs in RC. Due to the exponential growth of the Hilbert space dimension obtained by increasing the number of quantum elements small quantum systems are already sufficient for time series prediction. Here, we demonstrate that three-dimensional complex systems can already well be predicted by quantum reservoir computing (QRC) with a quantum reservoir consisting of the minimal number of qubits necessary for this task, namely four. This is achieved by optimizing the encoding of the data, using spatial and temporal multiplexing and recently developed read-out-schemes that also involve higher exponents of the reservoir response. We outline, test and validate our approach using eight prototypical three-dimensional chaotic systems. Both, the short-term prediction and the reproduction of the long-term system behavior (the system's "climate") are feasible with the same setup of optimized hyperparameters [1]. Our results may be a further step towards the realization of a dedicated small quantum computer for prediction tasks in the NISQ-era.

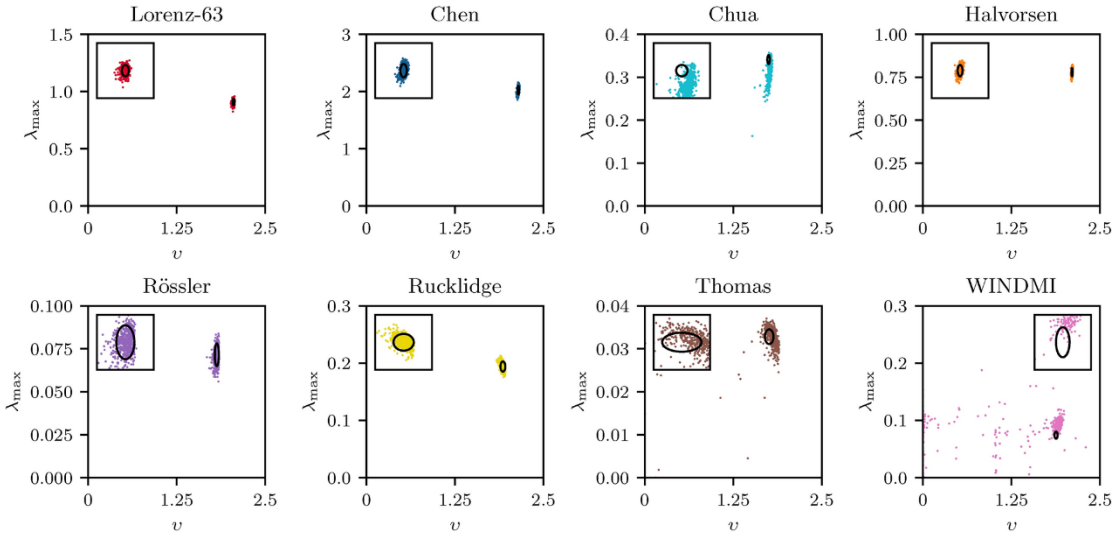

Figure 1: Distributions of the QRC-based predicted climate for the eight forecasted chaotic systems as measured with the largest Lyapunov exponent and the correlation dimension. Each dot represents one of 500 forecasted trajectories for all eight chaotic systems. The black ellipses show the three standard deviation errors of the largest Lyapunov exponent and the correlation dimension calculated from simulations of the respective systems.

References

[1] J. Steinegger, C. Räth, *Scientific Reports*, 15 (2025) 6201.