Neuromorphic Quantum Computing for Prediction and Optimization (NeMoQC)

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Summary

The application of AI-based forecasting methods has led to great progress in the prediction of complex systems. Among the AI-methods being used reservoir computing (RC) turns out to be so far the most promising approach as it combines superior prediction results with little CPU-needs for training. In Quantum Reservoir Computing (QRC) the reservoir that is commonly a random network, is replaced by a system of entangled qubits. Using a spin-network as ad hoc quantum reservoir it was demonstrated that a NARMA process can be well predicted using as few as 10 qubits [1]. Our recent first results suggest that even a 4-6 qubit system may be sufficient to predict the Lorenz-system as well as with "conventional" RC [2].
In the forthcoming research project "Neuromorphic Quantum Computing (NeMoQC)" within the framework of the DLR Quantum Computing Initiative (QCI) we will now investigate systematically which quantum reservoirs are best suited for prediction and optimization tasks. In a software/hardware codesign we will seek for hardware realizations of QRC. Further, these newly developed QC-based forecasting and optimization methods are to be utilized in real world applications. Industrial partners for both the hardware design and the applications in real world use cases are welcome to join our project.
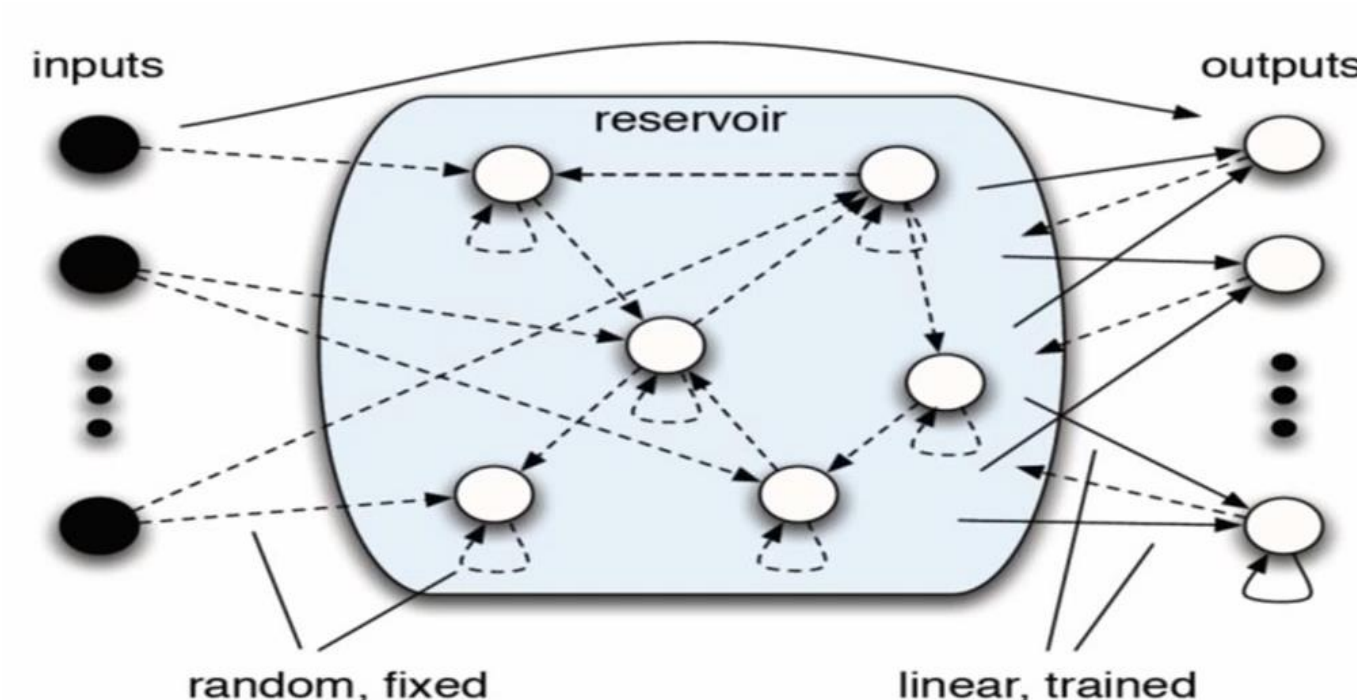[1] R. Martinez-Pena et al., PRL, 127, 100502 (2021)
[2] J. Steinegger, Masterthesis LMU (ongoing)
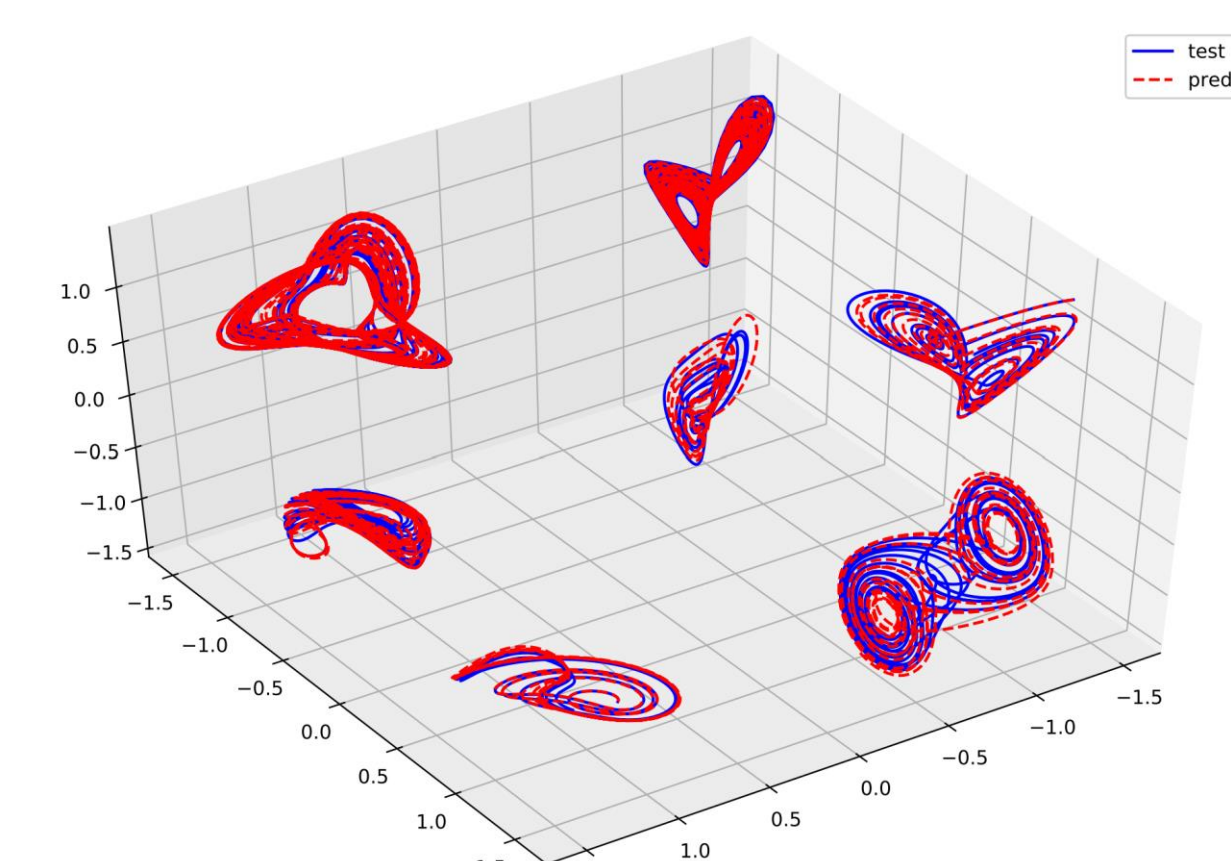
Making Predictions...

... is certainly a human desire and one of the great challenges in time series analysis.

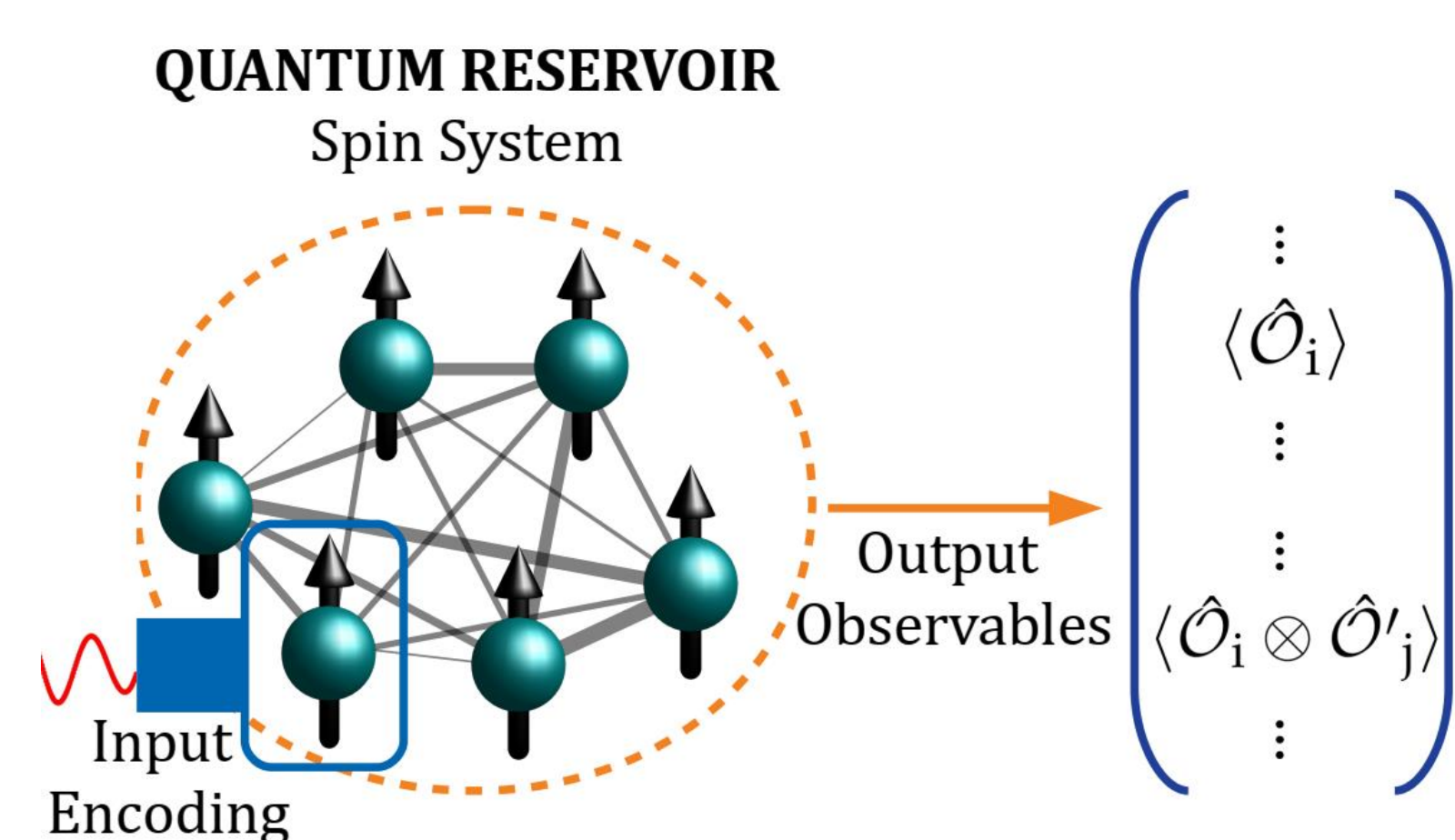## Reservoir Computing (RC) as neuromorphic AI concept...

...represents the so far best-suited AI method for the prediction of nonlinear complex systems.

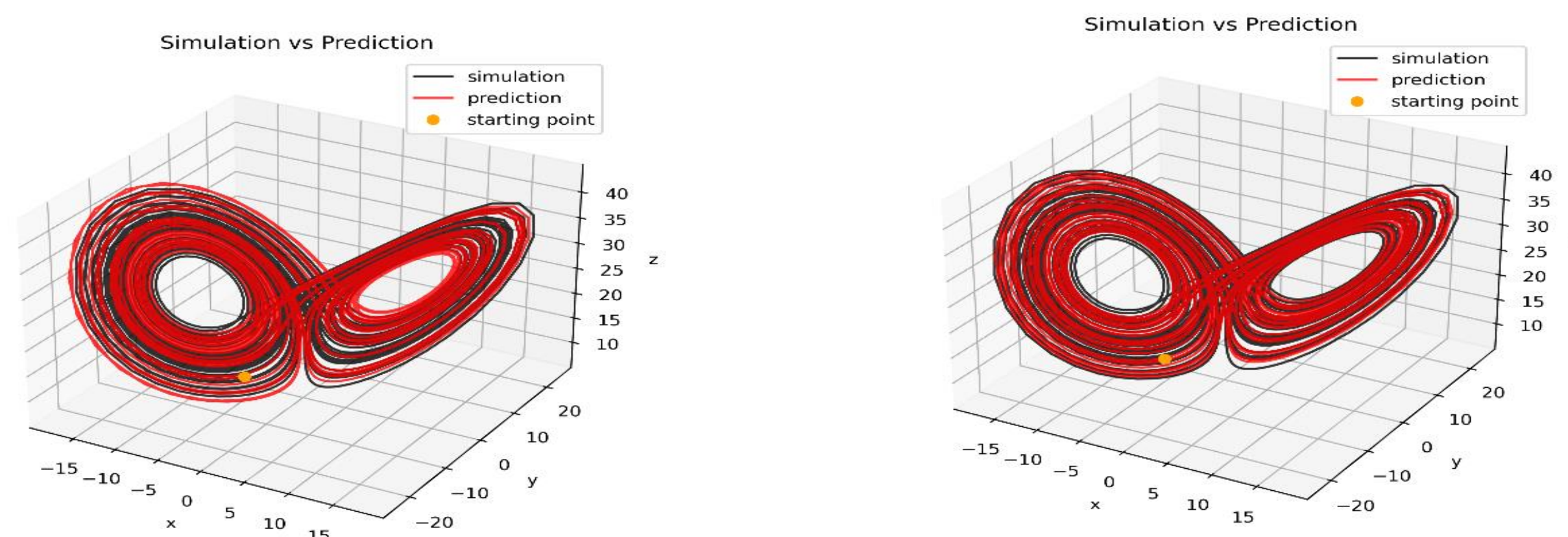## With RC-based methods....

...it is nowadays possible to simulaneously predict several chaotic systems.

In Quantum Reservoir Computing (QRC)....

...the reservoir is formed by a quantum system consisting of entangled qubits.

First simulation results suggest....

...that very small quantum systems consisting of four (left) or six (right) qubits are capable to make reliable predictions of a chaotic system.

NeMoQC....

...does QRC really yield safe and reliable forecasts?

...are such small quantum systems consisting of 4-10 qubits really sufficient to replace conventional reservoirs with a few hundred nodes?

...how do the prediction and optimization results depend on the type and strength of the interaction between the qubits?

...what is thus the optimal setup of a quantum reservoir ? And why?

....how is the practicability of the simulation results?

...how can a possible hardware realization of a quantum reservoir computer look like?

We are looking for....

...partners from industry, who want to develop with us prototypical quantum reservoir computers by hardware-software codesign on the basis of our theoretical results.

...partners from industry, who want to take part in our efforts to optimize QRC and/or who want to apply the newly gained results directly to their own use cases in the realms of optimization and/or prediction.

Let us achieve together a quantum leap in the prediction and optimization of complex systems by quantum reservoir computing!