Quantum reservoir computing in finite dimensions

Rodrigo Martínez-Peña[1]
Juan-Pablo Ortega[2]

[1]*Donostia International Physics Center, Paseo Manuel de Lardizabal 4, E-20018 San Sebastián, Spain*
[2]*Division of Mathematical Sciences, Nanyang Technological University, 21 Nanyang Link, Singapore 637371*

rmartinez@ifisc.uib-csic.es

Quantum reservoir computing (QRC) is a machine learning technique where complex quantum systems are exploited to solve temporal tasks, such as predicting chaotic time series and complex spatiotemporal dynamics [1]. Most existing results in the analysis of QRC systems with classical inputs have been obtained using the density matrix formalism [2]. Our work shows that alternative representations can provide better insights when dealing with design and assessment questions. It has been shown that these vector representations yield state-affine systems (SAS) previously introduced in the classical reservoir computing literature and for which numerous theoretical results have been established. This connection has been used to show that various statements in relation to the fading memory (FMP) and the echo state (ESP) properties are independent of the representation, and also to shed some light on fundamental questions in QRC theory in finite dimensions. Our conclusions can be summarised as: the necessary and sufficient condition that makes a quantum reservoir valuable is strictly contractive dynamics towards input-dependent fixed points. Figure 1 is an illustrative example of our theoretical results. In this example, a single qubit is driven by a temporal signal, and having an input-dependent (bottom) fixed point or not (top) completely determines the usefulness of the system.

References

[1] Fujii, K., & Nakajima, K. (2017). Physical Review Applied, 8(2), 024030.
[2] Chen, J. (2022). Ph. D. thesis, UNSW Sydney).

Figures

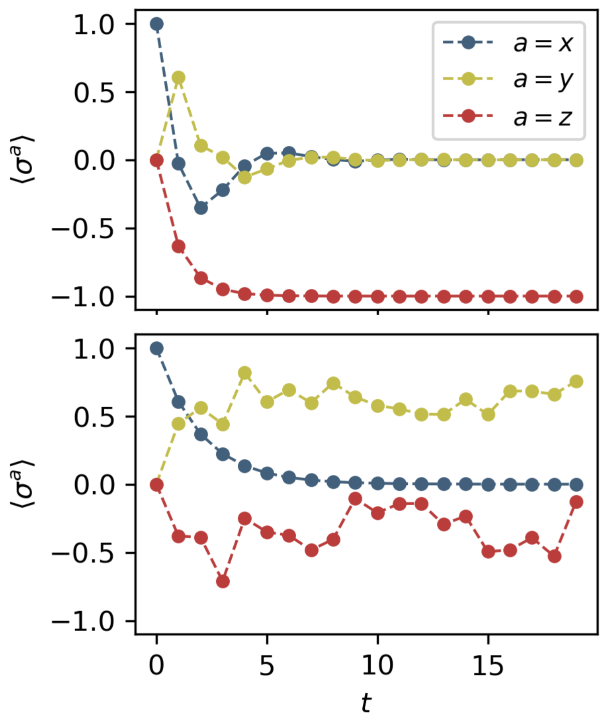

Figure 1: Dynamics of single-qubit observables when driven by a temporal input signal. Top picture represents an input-independent fixed point case while the bottom picture represents an input-dependent fixed point case.