

Quantum Reservoir Computing

Jacob Cybulski

Enquanted, Melbourne, Australia

jacob@enquanted.com

<https://jacobcybulski.com/>

Abstract

The standard approach to developing Quantum Machine Learning (QML) models, such as Quantum Neural Networks (QNNs), relies on Variational Quantum Algorithms (VQAs). Because VQAs require an iterative process interweaving classical parameter optimization with intermediate quantum model execution, they remain computationally expensive. This inefficiency becomes a severe bottleneck when handling dynamic temporal data, scaling to large quantum models, or relying on quantum simulators.

Quantum Reservoir Computing (QRC) offers a highly efficient, hybrid quantum-classical alternative for evaluating complex dynamic models. The core of the QRC framework is the “reservoir”—a sparsely connected QNN with fixed, randomly initialized weights that remain entirely untrained. The reservoir functions to project an input signal into a high-dimensional, non-linear dynamic representation within a Hilbert space. This expanded representation is then passed to a simple “readout” layer, typically a classical ridge regression, which is inexpensively trained to map the projection to a desired output. A critical requirement for this architecture is the Echo State Property (ESP), or “fading memory,” ensuring the reservoir's state is determined by the history of the input.

This presentation outlines the principles of QRC architecture, demonstrates working examples of QRC model execution, and details practical applications in time-series forecasting and signal processing. Furthermore, it will present unique insights from ongoing research investigating the phenomenon of memory duality that emerges within specific QRC model topologies.

Keywords:

Quantum Machine Learning, Quantum Reservoir Computing, Hilbert Space, Time-Series Forecasting, Signal Processing, Memory Duality

Bio Note



Jacob Cybulski is the founder of Enquanted, providing research, training and consulting services in quantum computing. Jacob's projects involve quantum machine learning for understanding complex data, as well as, development of algorithms and applications for prediction and anomaly detection in business, engineering, and science. He is dedicated to education and promotion of quantum technology. Jacob's work also concerns classical machine learning, business analytics and data visualisation. He collaborates internationally with a wide network of quantum researchers and developers.