Optimal quantum reservoir computing for the NISQ era

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Quantum reservoir computing (QRC) [1] has demonstrated to excel both in classical and quantum machine learning (QML) tasks. It exploits the quantum properties of physical systems and provides an easy training strategy, achieving excellent results. In gate-based quantum computation, QRC consists of a random quantum circuit applied to an initial state, which encodes the input data. The goal of the quantum reservoir is to extract valuable information from the input state, so that the measurements of simple local operators are useful features to predict the output. These features are then fed to a classical machine learning algorithm, typically a linear model. The design of the quantum reservoir determines the performance of the model, and thus selecting optimal quantum reservoirs is of vital importance. The majorization principle has proven to be an indicator of complexity of random quantum circuits [2]. Compared to other complexity criteria, such as the entanglement spectrum, evaluating the majorization in a quantum circuit requires significantly less operations. This makes this criterion suitable for the NISQ era, where quantum computation must be performed with limited quantum resources. In this work, the majorization criterion is used to design the optimal quantum reservoir in terms of performance in QML. The resulting quantum circuits are easily realised in noisy intermediate-scale quantum (NISQ) computers, and present a significant advantage over the commonly used Ising model. The performance of QRC is assessed using different families of quantum circuits, which have different complexity according to the majorization principle. Also, we study the number of gates needed for each family to obtain its optimal performance. In NISQ devices, the number of quantum gates used in a circuit should be as small as possible to avoid error propagation due to large error rates and short coherence times. We prove that the optimal quantum circuits provided in this work require significantly less quantum gates that the Ising model. The optimality of the quantum reservoir is illustrated by solving a quantum chemistry problem.

Figures

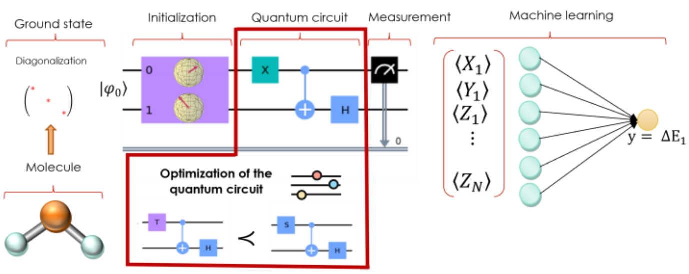

Figure 1: Pipeline used to train the quantum reservoir computing model.

References

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