Deep quantum neural networks equipped with the backpropagation algorithm

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Abstract

Quantum neural networks, typically structured as parameterized quantum circuits, merge the principles of quantum mechanics with the capabilities of neural networks. When dividing general quantum neural networks into multiple layers and restricting operations to be performed only between the nearest neighboring layers, a layer-by-layer deep quantum neural network can be designed. Tailored for this specialized structure of deep quantum neural networks, we design a unique quantum backpropagation algorithm for training. We analyze the training efficiency in terms of the required number of quantum copies for each training data per training iteration. Our analysis suggests that the quantum backpropagation algorithm is more efficient than traditional training algorithms in specific scenarios, particularly when the width of the hidden layers is smaller than the width of the input and output layers in the deep quantum neural network. Our numerical demonstrations highlight the remarkable learning ability of deep quantum neural networks, as well as the effectiveness of the quantum backpropagation algorithm in learning quantum channels.

Figures

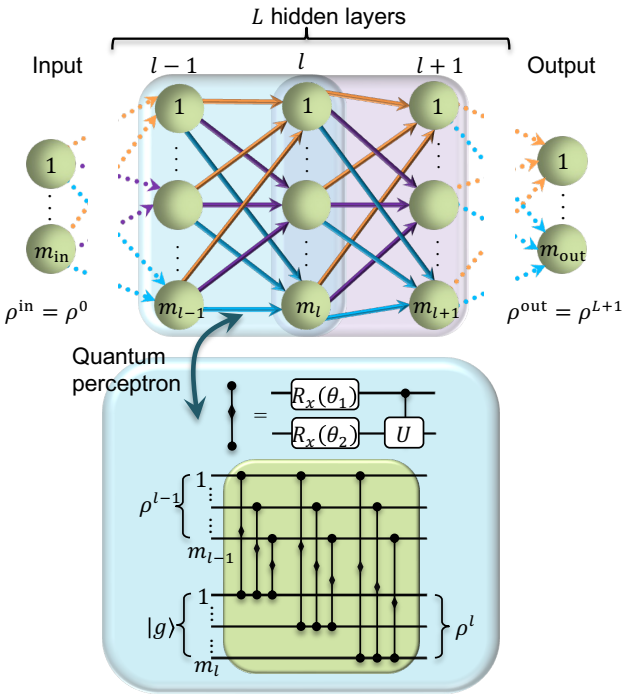

Figure 1: Schematic illustration of deep quantum neural networks.

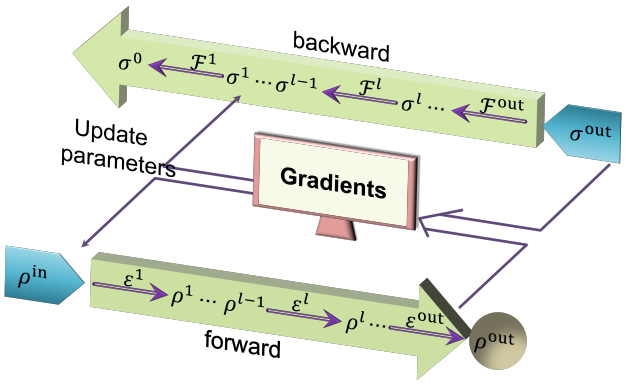

Figure 2: Exhibition of the backpropagation algorithm.

References

[1] Pan X*, **Lu Z***, et al., Nature Communications 14, 4006 (2023).