Training embedding quantum kernels with quantum neural networks

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Abstract

Kernel methods play a crucial role in machine learning and the Embedding Quantum Kernels (EQKs), an extension to quantum systems, have shown very promising performance. However, choosing the right embedding for EQKs is challenging. We address this by proposing a *p*-qubit Quantum Neural Network (QNN) based on data re-uploading to identify the optimal *q*-qubit EQK for a task (*p*-to-*q*). This method requires constructing the kernel matrix only once, offering improved efficiency. In particular, we focus on two cases: *n*-to-*n*, where we propose a scalable approach to train an *n*-qubit QNN, and *1*-to-*n*, demonstrating that the training of a single-qubit QNN can be leveraged to construct powerful EQKs. We will explore relevant applications in realistic scenarios such as satellite image classification and classification of neutrino flavors from IceCube.

References

[1] P. Rodriguez-Grasa, Y. Ban, & M. Sanz. Training embedding quantum kernels with data re-uploading quantum neural networks. ArXiv: 2401.04642 (2024).

[2] P. Rodriguez-Grasa, R. Farzan-Rodriguez, G. Novelli, Y. Ban, & M. Sanz. Satellite image classification with quantum neural network enhanced quantum kernels. *In preparation*.

[3] P. Rodriguez-Grasa, P. Zhelnin, G. Gatti, J. Lazar, C. A. Arguelles, & M. Sanz. Neutrino flavor classification with quantum processors. *In preparation*.

Figures

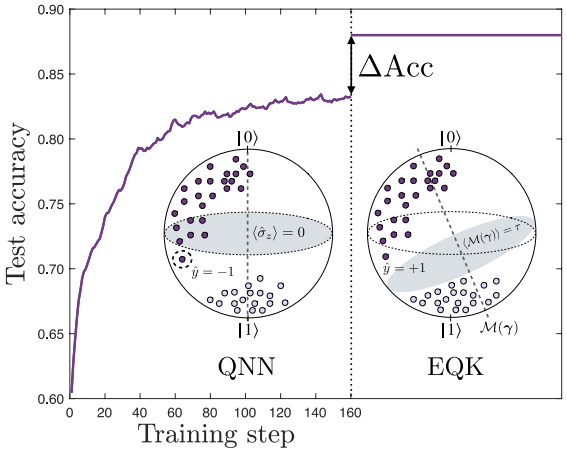

Figure 1: A schematic illustration of how a QNN can enhance classification accuracy.

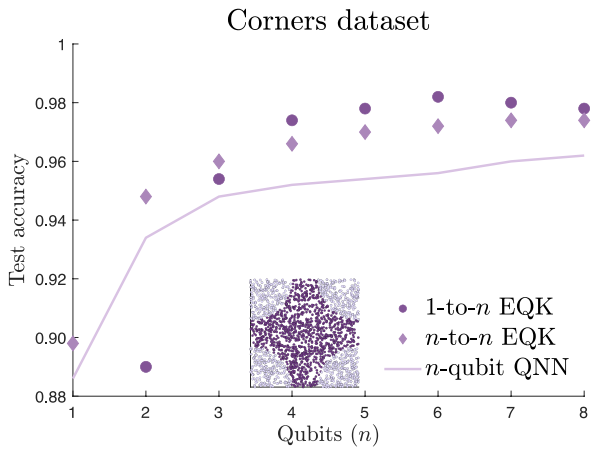

Figure 2: Test accuracies for two QNN-enhanced EQK architectures for synthetic data