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Quantum Convolutional Neural Network Classifier with 2-Dimensional Tensor Networks

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The success of convolutional neural networks (CNN) in image classification has prompted the development of various quantum and quantum-inspired algorithms seeking to perform the very task and explore possible advantages. A recently proposed framework, quantum convolutional neural networks (QCNN), has found great potentials in solving physical problems, yet its capacity of performing other machine learning tasks such as image classification remains to be explored. Replacing convolution kernels with variational quantum circuits (VQCs) may benefit possible quantum advantages, but its simulation suffers poor efficiency as the number of qubits becomes large. We present an effective approach to study the performance of QCNN in classifying classical images using convolution kernels based on Projected Entangled Pair States (PEPS), a type of tensor networks (TN) able to capture 2-dimensional correlations, which has proven capable of efficiently simulating generic quantum circuits. We show that a QCNN model with single PEPS convolutional layer achieves similar accuracy to other TN-based machine learning models on the MNIST and Fashion-MNIST datasets with the bond dimension needed much lower. An interesting finding is that the accuracies vary little with the bond dimension χ of the PEPS kernel, and a χ as low as 2 retains similar performance, implying that low entanglement settings could work well for VQC-QCNN.

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