Let the Quantum Creep In: Designing Quantum Neural Network Models by Gradually Swapping Out Classical Components

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Artificial Intelligence (AI), with its multiplier effect and wide applications across multiple areas, could potentially be one of the most important applications of quantum computing. Since modern AI systems are often built on neural networks, the design of quantum neural networks is a key aspect for integrating quantum computing into AI. To provide a more fine-grained characterization of the impact of quantum components on the performance of neural networks, we investigate a framework where classical neural network layers are gradually replaced by quantum layers that have the same type of input and output while keep the flow of information between layers unchanged, which differs from the usual end-to-end quantum model. We start with a simple three-layer classical neural network without any normalization layers or activation functions, and gradually change the classical layers to the corresponding quantum versions, either first proposed in this paper (`FlippedQuanv3x3`) or following methods proposed in previous research (`DataReUploadingLinear`) [1]. Numerical experiments were conducted on image classification datasets such as the MNIST, FashionMNIST and CIFAR-10 datasets to demonstrate the change of performance brought by the quantum components. Through this framework, our research shed new light on the design of future quantum neural network models: instead of trying to find the quantum silver bullet by developing an end-to-end quantum model, we should search for methods and frameworks that could harness the advantages from both classical and quantum worlds.

[1] Peiyong Wang et al., "Quantum Hamiltonian Embedding of Images for Data Reuploading Classifiers" To appear.