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# Efficient training of layerwise-commuting PQCs with parallel gradient estimation

Variational quantum algorithms, such as the variational quantum eigensolver (VQE), have a very high cost due to the large number of measurement outcomes that must be acquired from the quantum device during training. This is due in large part to the use of the parameter shift rule for estimating the gradient at each step, which requires two circuit evaluations per parameter. It was recently shown that if all the gate generators in the ansätz commute with each other, then the complete gradient vector can be found from a single evaluation of an augmented circuit (Bowles et al., 2023), and this has the potential to significantly reduce the quantum cost and avoid barren plateau-related issues. Unfortunately, this is quite a severe restriction, as it prevents the ansätz from having a nontrivial dynamical Lie algebra (DLA), which implies a lower expressibility. In order to obtain a more expressive ansätz than permitted by the commutation requirement, we construct it iteratively and train it in a layerwise fashion using the parallel gradient method. We benchmark our approach against several widely used ansätze from the literature, demonstrating that it requires fewer circuit evaluations than standard shift-based methods. We highlight the efficiency of our construction through both a VQE simulation of a random Heisenberg model and a quantum state learning algorithm.

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