Avoiding barren plateaus using classical shadows

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Variational quantum algorithms (VQAs) are promising algorithms for achieving quantum advantage on near-term devices. The quantum hardware is used to implement a variational wave function and measure observables, whereas the classical computer is used to store and update the variational parameters. The optimization landscape of expressive variational ansätze is however dominated by large regions in parameter space, known as barren plateaus (BPs)[1-3], with vanishing gradients which prevents efficient optimization.

In this work, we propose a general algorithm to avoid BPs in the initialization and throughout the optimization. To this end, we define a notion of weak barren plateaus (WBP) based on the entropies of local reduced density matrices. The presence of WBPs can be efficiently quantified using recently introduced shadow tomography[4] of the quantum state with a classical computer.

We demonstrate that avoidance of WBPs suffices to ensure sizable gradients in the initialization. In addition, we demonstrate that decreasing the gradient step size (controlled by the learning rate η), guided by the entropies allows avoiding WBPs during the optimization process. This paves the way for efficient BP free optimization on near-term devices.

References

[1] McClean et al., Nat Commun **9**, 4812 (2018)
[2] Cerezo et al., Nat Commun **12**, 1791 (2021)
[3] Holmes et al., PRX Quantum **3**, 010313 (2022)
[4] Huang et al., Nat Phys **16**, 1050-1057 (2020)

Figures

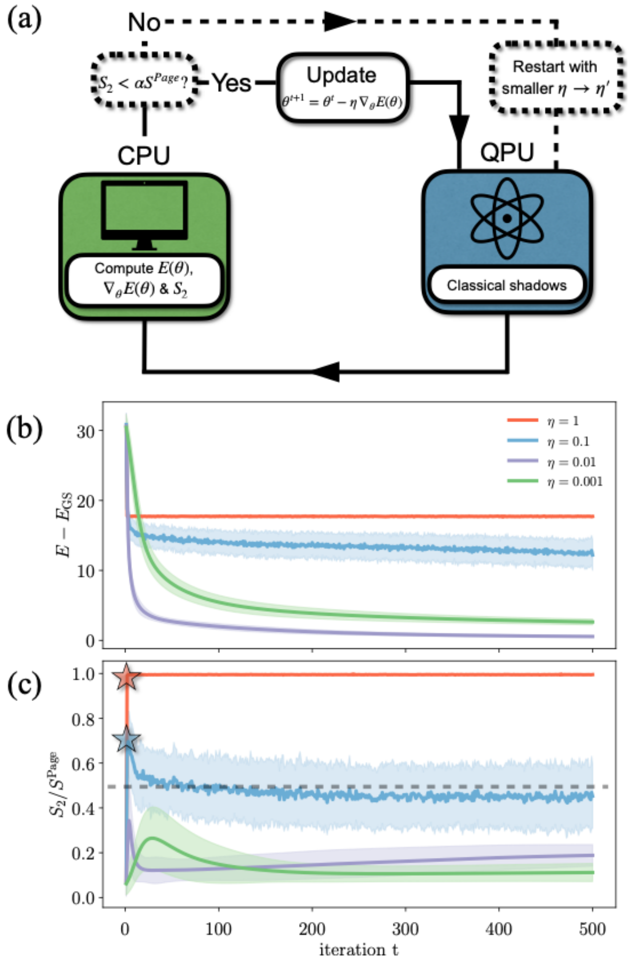

Figure 1: (a) Schematic illustration of the WBP avoidance procedure using classical shadows in VQAs. (b) Energy expectation value during the VQA optimization for different learning rates η. (c) Large learning rates lead to fast growth in entanglement entropy. A nearly maximal value (Page value) coincides with a WBP and poor optimization performance. Once a WBP is encountered, we restart the VQA with a smaller learning rate.