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VARIATIONAL QUANTUM ALGORITHMS: MACHINE LEARNING, MATHEMATICAL FOUNDATIONS AND IMPLEMENTATIONS

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ABSTRACT

Variational Quantum Algorithms (VQAs) have evolved as a top contender in the reality of quantum computation, considering the Noisy Intermediate-Scale Quantum (NISQ) phase [Bayad, KS]. The optimization problems can be solved based on shallow quantum circuits, with the help of classical numerical routines, by the virtue of their hybrid quantum classical structure [GGL]. This paper will provide an in-depth discussion of VQAs in machine learning with a special focus on the mathematical basis of expressivity, optimization geometry, and convergence behaviour. With the assistance of the tools of functional analysis, operator theory, and quantum information geometry, we derive the structure of parameterized quantum circuits and examine the landscape characteristics of variational loss functions. We also apply a number of variational quantum machine learning models, the Variational Quantum Classifier, and Quantum Neural Networks, to simulate quantum processors. Numerical experiments indicate that VQAs can be competitive in smaller-scale classification tasks but that noise, the structure of the ansatz and the stability of optimization have a significant impact on performance. The findings demonstrate the potential and constraints of VQAs in the available quantum technologies and inform future algorithm and hardware development [Simsek2019, Simsek2021].

***K*eywords** Variational Quantum Algorithms · Quantum Machine Learning · Parameterized Quantum Circuits · Hybrid Quantum–Classical Optimization

References

[1] Schuld, M., Bocharov, A., Svore, K., and Wiebe, N. Circuit-centric quantum classifiers. Physical Review A, 101(3), 2020. DOI: https://doi.org/10.1103/PhysRevA.101.032308

[2] Cerezo, M., Arrasmith, A., Babbush, R., Benjamin, S. C., Endo, S., Fujii, K., ... & Coles, P. J. (2021). Variational quantum algorithms. Nature Reviews Physics, 3(9), 625-644.

[3] McClean, J.R., Boixo, S., Smelyanskiy, V.N. et al. Barren plateaus in quantum neural network training landscapes. Nat Commun 9, 4812 (2018). https://doi.org/10.1038/s41467-018-07090-4

[4] Havlíček, V., Córcoles, A.D., Temme, K. et al. Supervised learning with quantum-enhanced feature spaces. Nature 567, 209–212 (2019). https://doi.org/10.1038/s41586-019-0980-2

[5] Preskill, J. Quantum Computing in the NISQ era and beyond. Quantum, 2, 2018. https://doi.org/10.22331/q-2018-08-06-79

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