Photonic counterdiabatic quantum optimization algorithm

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Abstract

Harnessing usefulness from current noisy intermediate-scale quantum (NISQ) computers has emerged as one of the main objectives for the quantum computing community. Variational quantum algorithms (VQAs) are the leading candidates to achieve this goal, making use of the limited quantum resources that existing NISQ computers offer. Currently, most research efforts are focused on encoding discrete optimization problems using qubit-based approaches, which are well-suited for implementation in superconducting circuits and trapped ions. On the other hand, photonic quantum computing (PQC) incorporates the continuous variable (CV) formalism allowing quantum information to be encoded in the quadrature amplitudes of an electromagnetic field known as qumodes. This encoding provides benefits in representing continuous optimization problems that are expensive to encode with qubits.
We propose photonic counterdiabatic quantum optimization (PCQO) algorithm depicted in Fig. 1, for the CV paradigm to solve problems suitable for currently available photonic devices [1]. PCQO is a hybrid quantum-classical algorithm designed by utilizing a photonic circuit ansatz and a classical optimization routine. The circuit ansatz is designed from a pool of Gaussian and non-Gaussian operations that are obtained by drawing inspiration from counterdiabatic (CD) protocols. Inspired by these CD protocol, our algorithm significantly reduces the required quantum operations for optimization as compared to other protocols like CV-QAOA. This reduction enables us to tackle non-convex continuous optimization and countably infinite integer programming within the near-term era of quantum computing. Through comprehensive benchmarking, we demonstrate that our approach outperforms existing state-of-the-art hybrid adiabatic quantum algorithms in terms of convergence and implementability. Remarkably, our algorithm offers a practical and accessible experimental realization, bypassing the need for high-order operations and overcoming experimental constraints.

References

[1] Chandarana P, Paul K, Garcia-de-Andoin M, Ban Y, Sanz M, Chen X. Communications Physics. 7(1) 2024, 315.

Figures

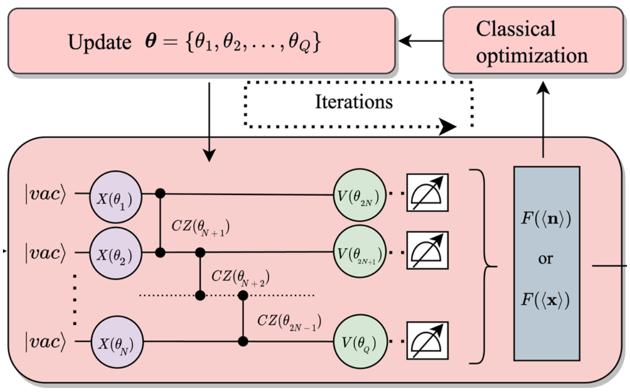

Figure1: A schematic diagram illustrating the photonic counterdiabatic quantum optimization (PCQO) algorithm. A logical problem, is encoded into F(n) or F(x) based on the problem type. The algorithm initiates with random parameter values and iteratively updates them through classical optimization, aiming to determine F(⟨n⟩) or F(⟨x⟩) until convergence is achieved. In the decoding phase performing measurements and extracting solutions from the minimum values, enables the representation of solutions in the form of the mean photon number ⟨n⟩ or the mean quadrature values ⟨x⟩.