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Digitized Counterdiabatic Quantum Computing

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I will introduce digitized counterdiabatic quantum computing (DCQC) as a novel paradigm for compressing digital quantum algorithms. It consists of a suitable digitization of the accelerated counterdiabatic dynamics of an adiabatic quantum computation, which encodes the chosen industry use case. I will exemplify DCQC to the class of optimization problems: digitized counterdiabatic quantum optimization (DCQO). In particular, I will present an advanced method called bias-field digitized counterdiabatic quantum optimization (bf-DCQO) for tackling combinatorial optimization problems on a digital quantum computer.

Along with the selected counterdiabatic (CD) terms in the adiabatic Hamiltonian, we introduce additional bias terms obtained either through classical methods, quantum annealers, or with iterations of DCQO itself. This combination of CD protocols and bias fields offers a way to address large-scale combinatorial optimization problems on current quantum computers with limited coherence time. By examining an all-to-all connected general Ising spin-glass problem, we observe a polynomial scaling enhancement in the time to solution compared to both DCQO and finite-time adiabatic quantum optimization. Moreover, the proposed method is purely quantum, eliminating the need for any classical optimization schemes. In this manner, we overcome the trainability drawbacks faced by variational quantum optimization algorithms.

Additionally, bf-DCQO significantly outperforms the quantum approximate optimization algorithm (QAOA) in terms of success probability and approximation ratio. Finally, I will present the experimental results of the proposed method on a trapped-ion quantum computer, tackling a fully connected spin-glass problem with 33 qubits and a maximum weighted independent set problem with 36 qubits. This represents the realization of the largest quantum computing problem of this nature, solved on a gate-based quantum computer by using a pure quantum algorithmic approach.

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