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Quantum Hamiltonian Descent

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Abstract

Gradient descent is a fundamental algorithm in both theory and practice for continuous optimization. Identifying its quantum counterpart would be appealing to both theoretical and practical quantum applications. A conventional approach to quantum speedups in optimization relies on the quantum acceleration of intermediate steps of classical algorithms, while keeping the overall algorithmic trajectory and solution quality unchanged. We propose Quantum Hamiltonian Descent (QHD), which is derived from the path integral of dynamical systems referring to the continuous-time limit of classical gradient descent algorithms, as a truly quantum counterpart of classical gradient methods where the contribution from classically-prohibited trajectories can significantly boost QHD's performance for non-convex optimization. Moreover, QHD is described as a Hamiltonian evolution efficiently simulatable on both digital and analog quantum computers. By embedding the dynamics of QHD into the evolution of the so-called Quantum Ising Machine (including D-Wave and others), we empirically observe that the D-Wave-implemented QHD outperforms a selection of state-of-the-art gradient-based classical solvers and the standard quantum adiabatic algorithm, based on the time-to-solution metric, on non-convex constrained quadratic programming instances up to 75 dimensions. Finally, we propose a “three-phase picture” to explain the behavior of QHD, especially its difference from the quantum adiabatic algorithm.

Bio

Jiaqi Leng is a fourth-year doctoral student in applied mathematics at the University of Maryland, College Park. He is also affiliated to the Joint Center for Quantum Information and Computer Science (QuICS) at Maryland. Jiaqi aims to leverage quantum computers to solve nonlinear and high-dimensional numerical problems that are intractable for classical computers. In particular, he tries to connect real-life computational tasks to quantum devices by providing end-to-end demonstrations of novel algorithmic designs. Jiaqi is advised by Dr. Xiaodi Wu.

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Zoom:

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11:30 – 12:20 pm