Adiabatic Spectroscopy and a Variational Quantum Adiabatic Algorithm

Benjamin F. Schiffer,[1,2,*] Jordi Tura,[3,1,2] and J. Ignacio Cirac[1,2]

[1] *Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany*

[2] *Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799 Munich, Germany*

[3] *Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, The Netherlands*

Preparing the ground state of a Hamiltonian is a problem of great significance in physics with deep implications in the field of combinatorial optimization. The adiabatic algorithm is known to return the ground state for sufficiently long preparation times which depend on the a priori unknown spectral gap. Our work relates in a twofold way. First, we propose a method to obtain information about the spectral profile of the adiabatic evolution. Second, we present the concept of a variational quantum adiabatic algorithm (VQAA) for optimized adiabatic paths [1]. We aim at combining the strengths of the adiabatic and the variational approaches for fast and high-fidelity ground state preparation while keeping the number of measurements as low as possible. Our algorithms build upon ancilla protocols which we present that allow to directly evaluate the ground state overlap. We benchmark for a non-integrable spin-1/2 transverse and longitudinal Ising chain with N = 53 sites using tensor network techniques. Using a black box, gradient-based approach, we report a reduction in the total evolution time for a given desired ground state overlap by a factor of ten, which makes our method suitable for the limited decoherence time of noisy-intermediate scale quantum devices.

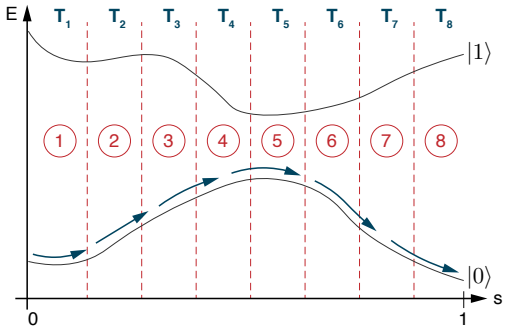

FIG. 1: Illustration of the hybrid algorithm by dividing the adiabatic path into eight chunks. The ground state and first excited state energies are shown for parametrized time $s = t/T$ from 0 to 1. For the black box optimization shown below, the adiabatic evolution time T is allocated evenly between the chunks of the adiabatic path (here $T_i = T/8\ \forall i \in \{1, 8\}$), so that the chunk positions become the variational parameters to be optimized, effectively controlling the density of adiabatic steps.

[1] B. F. Schiffer, J. Tura, and J. I. Cirac, Adiabatic spectroscopy and a variational quantum adiabatic algorithm, arXiv preprint arXiv:2103.01226 (2021).

* Correspondence: Benjamin.Schiffer@mpq.mpg.de