ERROR ROBUSTNESS OF QUANTUM ADIABATIC ALGORITHMS

STUDENTS: Uthkarsh Adya, Adina Ripin

Motivation & Objective

- Quantum adiabatic algorithms are of interest to quantum computing as an alternative to gate based quantum computing and are supposed to be more stable under errors , as method requires that qubits remain in their ground state the entire time[1].
- In this work we examine the error robustness of adiabatic quantum computing.

Project Background

Adiabatic algorithms are implemented as follows:

1. Design a Hamiltonian where the ground state of the system encodes the solution to a trivial optimization problem
2. Prepare the known ground state of a simple Hamiltonian on a set of qubits
3. Adiabatically change the system to the desired Hamiltonian:

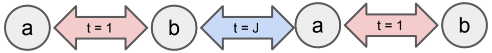
$$H(t) = f(t)H_0 + (1 - f(t))H_1$$

4. The system remains in ground state the final Hamiltonian and that will be the solution to the desired optimization problem

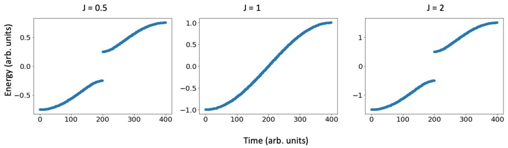
$$\rho = \frac{e^{-\hat{H}}}{Z} = \frac{e^{-a^\dagger \hat{H} a}}{Z} \text{ with } Z = Tr[e^{-\hat{H}}]$$

To study this problem, we can use a specific subclass of problems called gaussian free-fermion problems [2]. These models can be simulated scalably on classical computers.

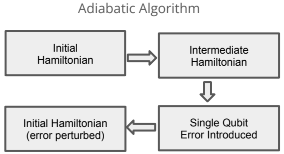
SSH Model

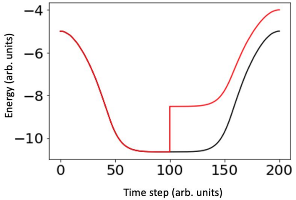


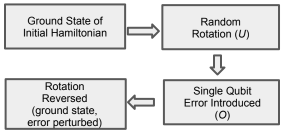
$$H_{SSH}[J] \equiv \sum_{i=1}^{n} t_i a_i^\dagger a_{i+1} + H.c., \; t_i = 1 \; if \; i \; odd, \; J \; if \; i \; even, \; a_{n+1} \equiv a_n$$



Methods: Quantifying Error

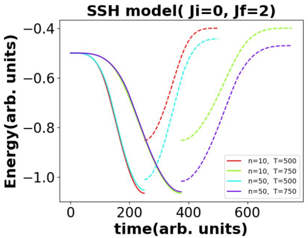


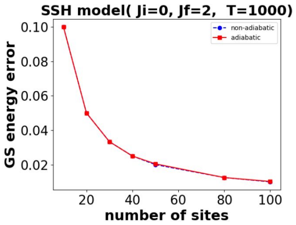




$$\Gamma_{err} = U^T O U \Gamma U^T O^T U$$

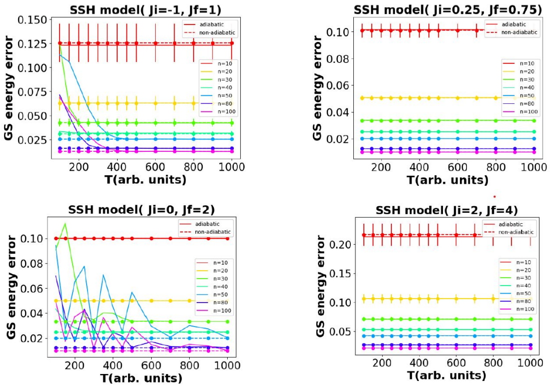
Results & Analysis: Error Scaling in Adiabatic Algorithms





- Adiabatic errors depend on the number of qubits and the total adiabatic algorithm time
- Errors reduce as you increase the number of qubits and the adiabatic algorithm time
- Error scaling with the number of qubits in adiabatic and is similar to that in non-adiabatic algorithms

More Results



- Adiabatic and non-adiabatic errors in GS energies, for different values of n (number of qubits), with respect to T (the total adiabatic algorithm time).
- The cases with the phase transition (at J=1) in the evolution require a larger T to stabilize because at J=1 the band gap collapses, making the thermal states more accessible.

Future Work, References, and Acknowledgments

- Theoretical analysis of our proposed error quantifying scheme to verify the computational results.
- Simulating non-gaussian models
- Characterize the errors in quantum adiabatic algorithms using non-gaussian models

Faculty: Sara Mouradian

[1] Trivedi, R., Rubio, A. F., & Ignacio Cirac, J. (2022, Dev 9). Quantum advantage and stability to errors in analogue quantum simulators arxiv.

[2] Surace, J., & Tagliacozzo, L. (2022, April 8). Fermionic Gaussian states: an introduction to numerical approaches. SciPost Phys, 1(Lect. Notes 54), 65.

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

ADVISER: Rahul Trivedi

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