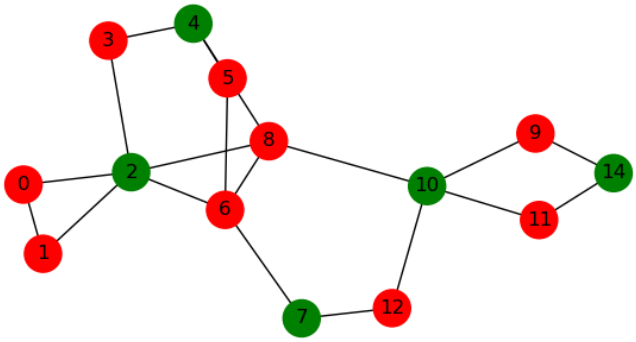
Topic 5: Solving MaxCut with TN imaginary time evolution

What to expect

In this project, you will learn how to tackle a challenging optimization problem by transforming it into the search for the ground state of an Ising spin chain and leveraging quantum imaginary time evolution to obtain the ground state. You will simulate the imaginary time evolution using tensor network techniques. Proficiency in Python coding and a basic understanding of tensor network theory are useful.

Overview



QUBO problems pose a significant challenge in optimization, falling under the category of NP-hard problems with diverse applications spanning from finance to machine learning. These problems can be effectively translated into a ground state search for an Ising Hamiltonian. We tackle a QUBO problem by simulating imaginary time evolution of an initial superposition of all possible configurations driven by the associated Ising Hamiltonian. We exploit TN imaginary time TDVP to scale up the optimization to large QUBO instances.

Tasks

- Generate random instances of the MaxCut problem, with different connectivity and topology.
- Map a MaxCut problem to a QUBO problem and solve it with a brute-force algorithm.
- Solve a MaxCut problem with imaginary time evolution (exact simulation).
- Solve a large MaxCut by simulating imaginary time evolution with TN.
- Investigate how the capability of finding low energy states depends on the features of the MaxCut graph (e.g., average connectivity and topology). Which class of graphs is more suitable for the TN ansatz?
- Investigate how the capability of finding low energy states depends on the bond dimension and on the number of steps in the time evolution.
- (Optional) Use OPES sampling[7] for studying how the energy distribution evolves during the process.
- (Optional) Compare the performances of imaginary-time evolution and variational GS search.

[7] M. Ballarin et al., arXiv pre-prints **2401.10330**, 10.48550/arXiv.2401.10330 (2024).