Transfer learning for different combinatorial optimization problems using the Quantum Approximate Optimization Algorithm

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QSOLID Quantum Computer in the Solid State

Abstract

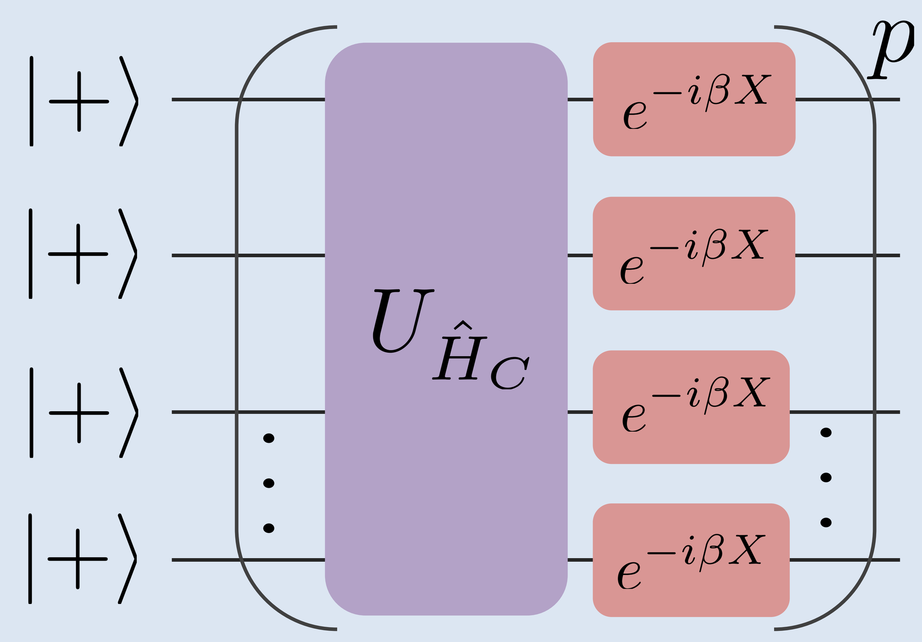
Solving combinatorial optimization problems (COPs) of the kind that can be expressed as Quadratic Unconstrained Binary Optimization (QUBO) is a promising application of quantum computation. The most studied algorithm for combinatorial optimization problems is the Quantum Approximate Optimization Algorithm (QAOA). Even though it is still unclear whether QAOA will provide any advantage compared to other algorithms, its simplicity makes it of great interest for analytical and practical purposes. In this work, we study the transfer learning capabilities of QAOA from the perspective of different COPs. To this end, we select small instances of well-known COPs, such as the Traveling Salesman Problem (TSP), the Bin Packing Problem (BPP), the Knapsack Problem (KP), Maximum Cut (MaxCut), and Maximal Independent Set (MIS) to find optimal β_p and γ_p parameters for p=10 in the QAOA algorithm. We compare how well the parameters adapt to the other problems by comparing the probability of obtaining the optimal solution. Among the different problems, BPP shows the best learning transfer capabilities.

Methodology

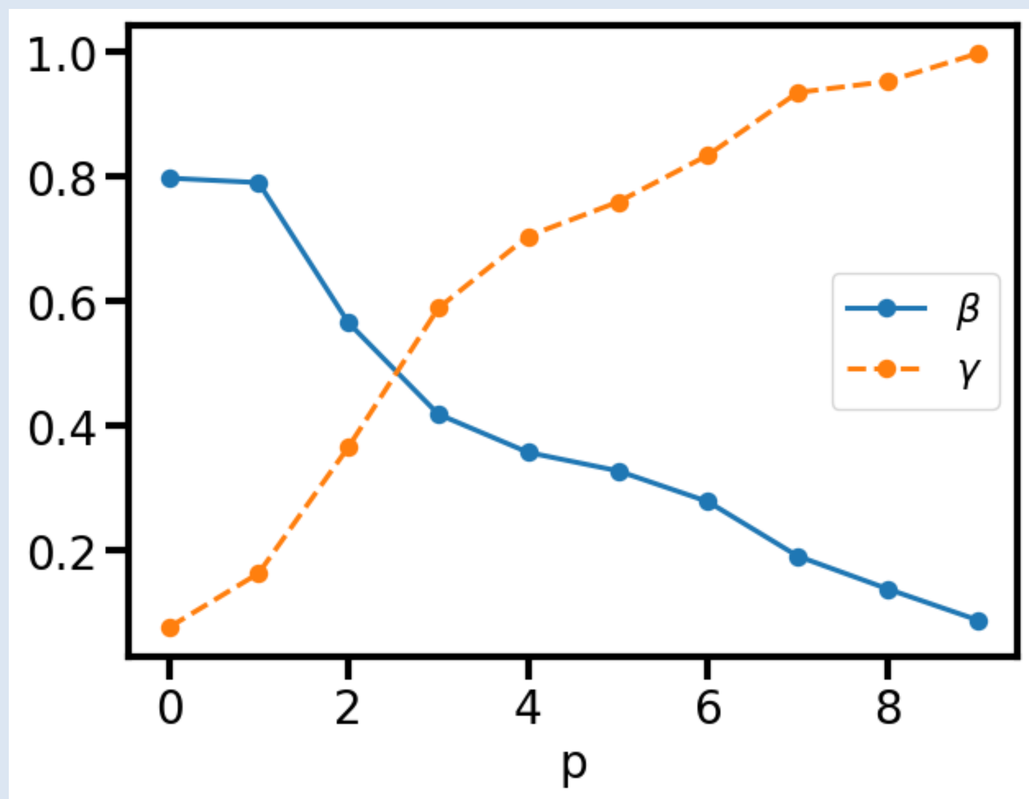
1. QUBO Formulation: Small size problem COP

2. Optimization γ_p and β_p using QAOA

$$U_{\hat{H}_C} = e^{-i\gamma \hat{H}_C} \qquad U_{\hat{H}_B} = e^{-i\beta \hat{B}}$$

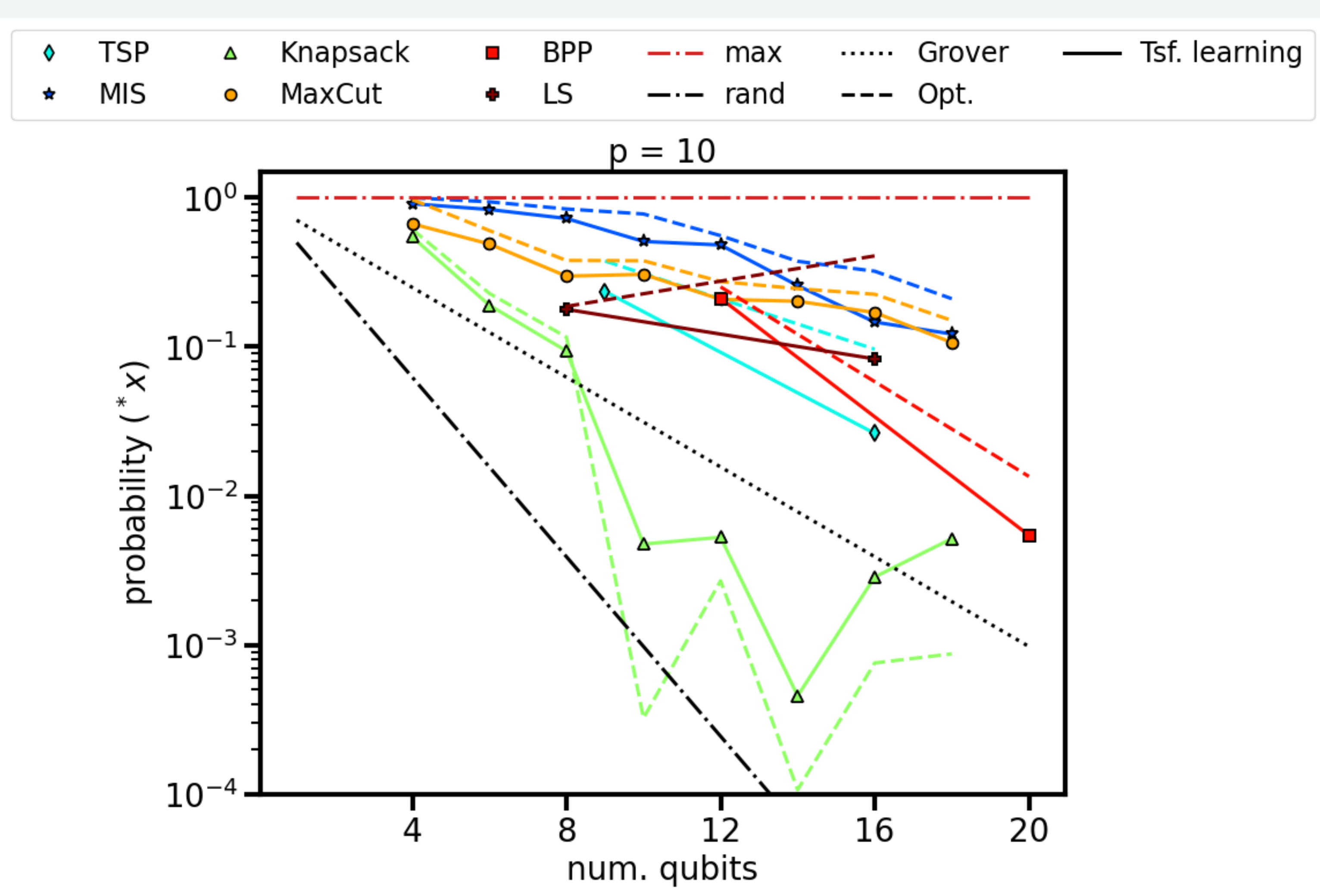


3. Use the β_p and γ_p parameters found in step 2 on other problems

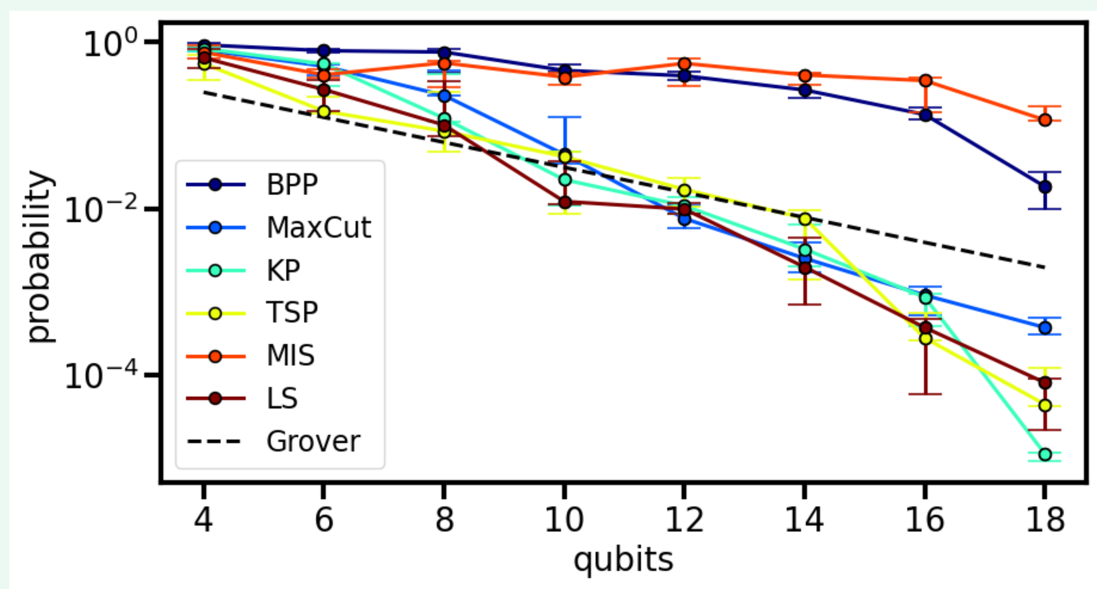


Results

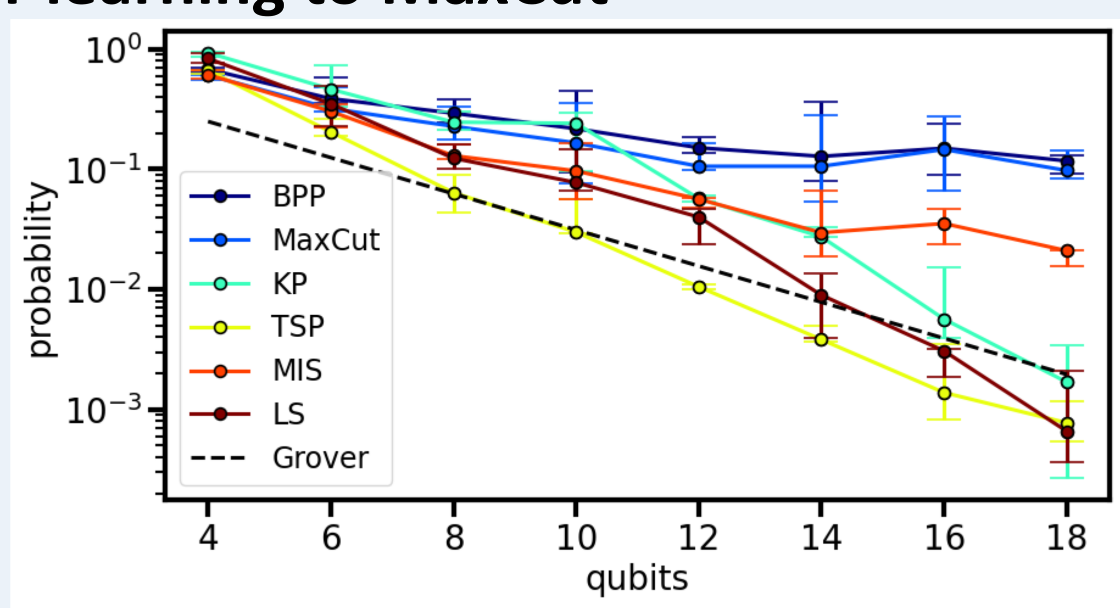
Transfer learning from the BPP - 3 items (12 qubits)



Transfer learning to MIS



Transfer learning to MaxCut



Conclusions

We have presented transfer learning for different COPs, a methodology that can reduce the requirements for optimization of the QAOA parameters using specific COPs. We show that BPP is an excellent candidate to transfer knowledge to other COPs. Using a small BPP with 12 qubits, we obtained results similar to doing the individual optimization on the specific problems.

SPONSORED BY THE Federal Ministry of Education and Research

The QSolid project acknowledges the support of the Federal Ministry of Education and Research (BMBF) within the framework programme "Quantum technologies – from basic research to market" (Grant No. 13N16149).