

William Cruz-Santos · Guillermo Morales-Luna

Approximability of Optimization Problems through Adiabatic Quantum Computation

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**William Cruz-Santos, Guillermo
Morales-Luna**



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Approximability of Optimization Problems through Adiabatic Quantum Computation William

Cruz-Santos,Guillermo Morales-Luna,2022-05-31 The adiabatic quantum computation AQC is based on the adiabatic theorem to approximate solutions of the Schrödinger equation The design of an AQC algorithm involves the construction of a Hamiltonian that describes the behavior of the quantum system This Hamiltonian is expressed as a linear interpolation of an initial Hamiltonian whose ground state is easy to compute and a final Hamiltonian whose ground state corresponds to the solution of a given combinatorial optimization problem The adiabatic theorem asserts that if the time evolution of a quantum system described by a Hamiltonian is large enough then the system remains close to its ground state An AQC algorithm uses the adiabatic theorem to approximate the ground state of the final Hamiltonian that corresponds to the solution of the given optimization problem In this book we investigate the computational simulation of AQC algorithms applied to the MAX SAT problem A symbolic analysis of the AQC solution is given in order to understand the involved computational complexity of AQC algorithms This approach can be extended to other combinatorial optimization problems and can be used for the classical simulation of an AQC algorithm where a Hamiltonian problem is constructed This construction requires the computation of a sparse matrix of dimension $2^n \times 2^n$ by means of tensor products where n is the dimension of the quantum system Also a general scheme to design AQC algorithms is proposed based on a natural correspondence between optimization Boolean variables and quantum bits Combinatorial graph problems are in correspondence with pseudo Boolean maps that are reduced in polynomial time to quadratic maps Finally the relation among NP hard problems is investigated as well as its logical representability and is applied to the design of AQC algorithms It is shown that every monadic second order logic MSOL expression has associated pseudo Boolean maps that can be obtained by expanding the given expression and also can be reduced to quadratic forms Table of Contents Preface Acknowledgments Introduction Approximability of NP hard Problems Adiabatic Quantum Computing Efficient Hamiltonian Construction AQC for Pseudo Boolean Optimization A General Strategy to Solve NP Hard Problems Conclusions Bibliography Authors Biographies

Quantum Robotics Prateek Tandon,Stanley Lam,Ben Shih,Tanay Mehta,Alex Mitev,Zhiyang Ong,2022-05-31 Quantum robotics is an emerging engineering and scientific research discipline that explores the application of quantum mechanics quantum computing quantum algorithms and related fields to robotics This work broadly surveys advances in our scientific understanding and engineering of quantum mechanisms and how these developments are expected to impact the technical capability for robots to sense plan learn and act in a dynamic environment It also discusses the new technological potential that quantum approaches may unlock for sensing and control especially for exploring and manipulating quantum scale environments Finally the work surveys the state of the art in current implementations along with their benefits and limitations and provides a roadmap for the future

Combinatorial Optimization Problems: Quantum Computing N.B. Singh, Combinatorial

Optimization Problems Quantum Computing is an introductory guide that bridges the gap between combinatorial optimization and quantum computing for absolute beginners This book unpacks fundamental concepts in optimization and explores how quantum computing can revolutionize the way we approach complex problems Through clear explanations and relatable examples readers will gain an understanding of both fields without needing any prior knowledge of quantum mechanics or advanced mathematics Ideal for those curious about the future of technology this book serves as a stepping stone into the fascinating world of quantum algorithms and their applications in optimization **Solving Optimization**

Problems Using Adiabatic Quantum Computing Kai Liu, 2018 The commercial D Waves quantum annealer has given rise to plenty of interests due to the reported quantum speedup against classical annealing In order to make use of this new technology a problem must be formulated into a form of quadratic unconstrained binary optimization QUBO or Ising model This thesis reports on case studies using a D Wave quantum annealer to solve several optimization problems and providing results validation using classical exact approaches In our thesis we briefly introduce several classical techniques designed for QUBO problems and implement two exact approaches With the proper tools a D Wave 2X computer consisted of 1098 active qubits is then evaluated for the Degree Constrained Minimum Spanning Tree and the Steiner Tree problems establishing their QUBO formulations are suitable for adiabatic quantum computers Motivated by the remarkable performance two more optimization problems are studied the Bounded Depth Steiner Tree problem and the Chromatic Sum problem We propose a new formulation for each problem The numbers of qubits dimension of QUBO matrices required by our formulations are $O(V^3)$ and $O(V^2)$ respectively where V represents the number of vertices *Lagrangian Duality and Adiabatic Quantum*

Computation for Constrained Optimization Problems Einar Gabbassov, 2022 The Quantum Approximate Optimization Algorithm QAOA is a heuristic method for solving unconstrained binary optimization problems with a gate based quantum computer The QAOA consists of a particular quantum circuit architecture together with a prescription for choosing the parameterization of the circuit The first part of the thesis studies both the architecture and optimal parameterization of the QAOA circuit After reviewing the necessary mathematical and physical background we derive QAOA from scratch and discuss some of its properties The second part of the thesis focuses on solving constrained combinatorial optimization problems in the setting of fault tolerant quantum computation and presents a novel Lagrangian duality approach to Discretized Adiabatic Quantum Computation DAQC The proposed method allows for building highly resource efficient and parallelizable quantum circuits The thesis presents numerical evidence that demonstrates that the proposed approach gives the quadratic improvement in circuit complexity and evolution time over circuits derived from the traditional Quadratic Unconstrained Binary Optimization QUBO formalism We illustrate our findings in the benchmark of the QUBO and Lagrangian based DAQC on the NP complete 1D 0 1 knapsack problem

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