

William Cruz-Santos · Guillermo Morales-Luna

Approximability of Optimization Problems through Adiabatic Quantum Computation

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Einar Gabbassov



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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 Schr dinger 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 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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Table of Contents Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna

1. Understanding the eBook Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - The Rise of Digital Reading Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Advantages of eBooks Over Traditional Books
2. Identifying Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Approximability Of Optimization Problems Through Adiabatic Quantum Computation

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- User-Friendly Interface

4. Exploring eBook Recommendations from Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna

- Personalized Recommendations
- Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna User Reviews and Ratings
- Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna and Bestseller Lists

5. Accessing Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna Free and Paid eBooks

- Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna Public Domain eBooks
- Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna eBook Subscription Services
- Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna Budget-Friendly Options

6. Navigating Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna eBook Formats

- ePub, PDF, MOBI, and More
- Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna Compatibility with Devices
- Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna Enhanced eBook Features

7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
- Highlighting and Note-Taking Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
- Interactive Elements Approximability Of Optimization Problems Through Adiabatic Quantum Computation

Guillermo Morales Luna

8. Staying Engaged with Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
9. Balancing eBooks and Physical Books Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Setting Reading Goals Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Fact-Checking eBook Content of Approximability Of Optimization Problems Through Adiabatic Quantum Computation Guillermo Morales Luna
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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