

Jaroslav Adam Mischak

High-level Structures for Quantum Computing

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**Prateek Tandon, Stanley Lam, Ben
Shih, Tanay Mehta, Alex Mitev, Zhiyang
Ong**

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High-level Structures for Quantum Computing Jaroslaw Adam Mischczak, 2012 This book is concerned with the models of quantum computation Information processing based on the rules of quantum mechanics provides us with new opportunities for developing more efficient algorithms and protocols However to harness the power offered by quantum information processing it is essential to control the behavior of quantum mechanical objects in a precise manner As this seems to be conceptually difficult at the level of quantum states and unitary gates high level quantum programming languages have been proposed for this purpose The aim of this book is to provide an introduction to abstract models of computation used in quantum information theory Starting from the abstract models of Turing machine and finite automata we introduce the models of Boolean circuits and Random Access Machine and use them to present quantum programming techniques and quantum programming languages Table of Contents Introduction Turing machines Quantum Finite State Automata Computational Circuits Random Access Machines Quantum Programming Environment Quantum Programming Languages Imperative quantum programming Functional Quantum Programming Outlook *High Level Structures for Quantum Computing* Jaroslaw Mischczak, 2022-05-31 This book is concerned with the models of quantum computation Information processing based on the rules of quantum mechanics provides us with new opportunities for developing more efficient algorithms and protocols However to harness the power offered by quantum information processing it is essential to control the behavior of quantum mechanical objects in a precise manner As this seems to be conceptually difficult at the level of quantum states and unitary gates high level quantum programming languages have been proposed for this purpose The aim of this book is to provide an introduction to abstract models of computation used in quantum information theory Starting from the abstract models of Turing machine and finite automata we introduce the models of Boolean circuits and Random Access Machine and use them to present quantum programming techniques and quantum programming languages Table of Contents Introduction Turing machines Quantum Finite State Automata Computational Circuits Random Access Machines Quantum Programming Environment Quantum Programming Languages Imperative quantum programming Functional Quantum Programming Outlook *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 by 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 Adiabatic Quantum Computation and Quantum Annealing Catherine C. McGeoch, 2022-06-01 Adiabatic quantum computation AQC is an alternative to the better known gate model of quantum computation The two models are polynomially equivalent but otherwise quite dissimilar one property that distinguishes AQC from the gate model is its analog nature Quantum annealing QA describes a type of heuristic search algorithm that can be implemented to run in the native instruction set of an AQC platform D Wave Systems Inc manufactures quantum annealing processor chips that exploit quantum properties to realize QA computations in hardware The chips form the centerpiece of a novel computing platform designed to solve NP hard optimization problems Starting with a 16 qubit prototype announced in 2007 the company has launched and sold increasingly larger models the 128 qubit D Wave One system was announced in 2010 and the 512 qubit D Wave Two system arrived on the scene in 2013 A 1 000 qubit model is expected to be available in 2014 This monograph presents an introductory overview of this unusual and rapidly developing approach to computation We start with a survey of basic principles of quantum computation and what is known about the AQC model and the QA algorithm paradigm Next we review the D Wave technology stack and discuss some challenges to building and using quantum computing systems at a commercial scale The last chapter reviews some experimental efforts to understand the properties and capabilities of these unusual platforms The discussion throughout is aimed at an audience of computer scientists with little background in quantum computation or in physics

Table of Contents Acknowledgments Introduction Adiabatic Quantum Computation Quantum Annealing The D Wave Platform Computational Experience Bibliography Author s Biography *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

Negative Quantum Channels James M. McCracken, 2022-05-31 This book is a brief introduction to negative quantum channels i.e linear trace preserving and consistent quantum maps that are not completely positive The flat and sharp operators are introduced and explained Complete positivity is presented as a mathematical property but it is argued that complete positivity is not a physical requirement of all quantum operations Negativity a measure of the lack of complete positivity is proposed as a tool for empirically testing complete positivity assumptions Table of Contents Preface Acknowledgments Introduction and Definition of Terms Tomography Non Positive Reduced Dynamics Complete Positivity Physical Motivation of Complete Positivity Measures of Complete Positivity Negative Channels Negative Channels with Diagonal Composite Dynamics Rabi Channels Physical Motivations for Sharp Operations Negative Qubit Channel Examples with Multi Qubit Baths Proposed Experimental Demonstration of Negativity Implications of Negative Channels Uses for Negative Channels Conclusions Bibliography Author's Biography

Quantum Computer Architecture Umar Farooq, 2014-10-29 Seminar paper from the year 2014 in the subject Computer Science Applied grade A course Advance Computer Architecture language English abstract Quantum Computers are evolving for more than a decade and they are closer to reality The field of quantum computing is too big to be described in one paper but the real motivation for the quantum computers is its architecture Firstly it is believed that classical computers can't use the quantum algorithms and operations secondly the programs running on the quantum computers can't run on traditional computer which is due to architecture and system The quantum computer architecture is the key to build a quantum computer The quantum computers are more complex than traditional computers This research paper will discuss the quantum computer architecture

Quantum Computing for Computer Architects Tzvetan S. Metodi, Frederic T. Chong, 2022-12-06 Quantum computation may seem to be a topic for science fiction but small quantum computers have existed for several years and larger machines are on the drawing table These efforts have been fueled by a tantalizing property while conventional computers employ a binary representation that allows computational power to scale linearly with resources at best quantum computations employ quantum phenomena that can interact to allow computational power that is exponential in the number of quantum bits in the system Quantum devices rely on the ability to control and manipulate binary data stored in the phase information of quantum wave functions that describe the electronic states of individual atoms or the polarization states of photons While existing quantum technologies are in their infancy we shall see

that it is not too early to consider scalability and reliability. In fact, such considerations are a critical link in the development chain of viable device technologies capable of orchestrating reliable control of tens of millions of quantum bits in a large scale system. The goal of this lecture is to provide architectural abstractions common to potential technologies and explore the systems-level challenges in achieving scalable fault-tolerant quantum computation. The central premise of the lecture is directed at quantum computation QC architectural issues. We stress the fact that the basic tenet of large scale quantum computing is reliability through system balance: the need to protect and control the quantum information just long enough for the algorithm to complete execution. To architect QC systems, one must understand what it takes to design and model a balanced fault-tolerant quantum architecture just as the concept of balance drives conventional architectural design. For example, the register file depth in classical computers is matched to the number of functional units, the memory bandwidth to the cache miss rate, or the interconnect bandwidth matched to the compute power of each element of a multiprocessor. We provide an engineering-oriented introduction to quantum computation and provide an architectural case study based upon experimental data and future projection for ion trap technology. We apply the concept of balance to the design of a quantum computer, creating an architecture model that balances both quantum and classical resources in terms of exploitable parallelism in quantum applications. From this framework, we also discuss the many open issues remaining in designing systems to perform quantum computation.

Quantum Computing for Computer Architects, Second Edition Tzvetan Metodiev, Arvin I. Faruque, 2022-06-01

Quantum computers can, in theory, solve certain problems far faster than a classical computer running any known classical algorithm. While existing technologies for building quantum computers are in their infancy, it is not too early to consider their scalability and reliability in the context of the design of large scale quantum computers. To architect such systems, one must understand what it takes to design and model a balanced fault-tolerant quantum computer architecture. The goal of this lecture is to provide architectural abstractions for the design of a quantum computer and to explore the systems-level challenges in achieving scalable fault-tolerant quantum computation. In this lecture, we provide an engineering-oriented introduction to quantum computation with an overview of the theory behind key quantum algorithms. Next, we look at architectural case studies based upon experimental data and future projections for quantum computation implemented using trapped ions. While we focus here on architectures targeted for realization using trapped ions, the techniques for quantum computer architecture design, quantum fault tolerance, and compilation described in this lecture are applicable to many other physical technologies that may be viable candidates for building a large scale quantum computing system. We also discuss general issues involved with programming a quantum computer as well as a discussion of work on quantum architectures based on quantum teleportation. Finally, we consider some of the open issues remaining in the design of quantum computers.

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