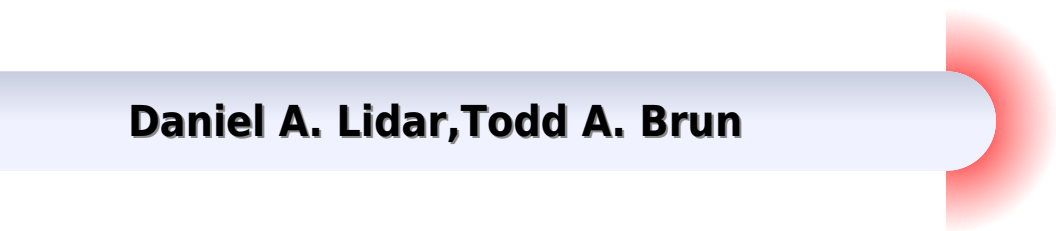




Quantum Error Correction And Fault Tolerant Quantum Computing

Daniel A. Lidar, Todd A. Brun



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Quantum Error Correction and Fault Tolerant Quantum Computing Frank Gaitan, 2018-10-03 It was once widely believed that quantum computation would never become a reality However the discovery of quantum error correction and the proof of the accuracy threshold theorem nearly ten years ago gave rise to extensive development and research aimed at creating a working scalable quantum computer Over a decade has passed since this monumental accomplishment yet no book length pedagogical presentation of this important theory exists Quantum Error Correction and Fault Tolerant Quantum Computing offers the first full length exposition on the realization of a theory once thought impossible It provides in depth coverage on the most important class of codes discovered to date quantum stabilizer codes It brings together the central themes of quantum error correction and fault tolerant procedures to prove the accuracy threshold theorem for a particular noise error model The author also includes a derivation of well known bounds on the parameters of quantum error correcting code Packed with over 40 real world problems 35 field exercises and 17 worked out examples this book is the essential resource for any researcher interested in entering the quantum field as well as for those who want to understand how the unexpected realization of quantum computing is possible

Quantum Error Correction and Fault Tolerant Quantum Computing - S Gaitan Frank Staff, 2007-10 It was once widely believed that quantum computation would never become a reality However the discovery of quantum error correction and the proof of the accuracy threshold theorem nearly ten years ago gave rise to extensive development and research aimed at creating a working scalable quantum computer Over a decade has passed since this monumental accomplishment yet no book length pedagogical presentation of this important theory exists Quantum Error Correction and Fault Tolerant Quantum Computing offers the first full length exposition on the realization of a theory once thought impossible It provides in depth coverage on the most important class of codes discovered to date quantum stabilizer codes It brings together the central themes of quantum error correction and fault tolerant procedures to prove the accuracy threshold theorem for a particular noise error model The author also includes a derivation of well known bounds on the parameters of quantum error correcting code Packed with over 40 real world problems 35 field exercises and 17 worked out examples this book is the essential resource for any researcher interested in entering the quantum field as well as for those who want to understand how the unexpected realization of quantum computing is possible *New Methods in*

Quantum Error Correction and Fault-tolerant Quantum Computing Christopher Chamberland, 2018 Quantum computers have the potential to solve several interesting problems in polynomial time for which no polynomial time classical algorithms have been found However one of the major challenges in building quantum devices is that quantum systems are very sensitive to noise arising from undesired interactions with the environment Noise can lead to errors which can corrupt the results of the computation Quantum error correction is one way to mitigate the effects of noise arising in quantum devices With a plethora of quantum error correcting codes that can be used in various settings one of the main challenges of quantum error

correction is understanding how well various codes perform under more realistic noise models that can be observed in experiments This thesis proposes a new decoding algorithm which can optimize threshold values of error correcting codes under different noise models The algorithm can be applied to any Markovian noise model Further it is shown that for certain noise models logical Clifford corrections can further improve a code's threshold value if the code obeys certain symmetries Since gates and measurements cannot in general be performed with perfect precision the operations required to perform quantum error correction can introduce more errors into the system thus negating the benefits of error correction Fault tolerant quantum computing is a way to perform quantum error correction with imperfect operations while retaining the ability to suppress errors as long as the noise is below a code's threshold One of the main challenges in performing fault tolerant error correction is the high resource requirements that are needed to obtain very low logical noise rates With the use of flag qubits this thesis develops new fault tolerant error correction protocols that are applicable to arbitrary distance codes Various code families are shown to satisfy the requirements of flag fault tolerant error correction We also provide circuits using a constant number of qubits for these codes It is shown that the proposed flag fault tolerant method uses fewer qubits than previous fault tolerant error correction protocols It is often the case that the noise afflicting a quantum device cannot be fully characterized Further even with some knowledge of the noise it can be very challenging to use analytic decoding methods to improve the performance of a fault tolerant scheme This thesis presents decoding schemes using several state of the art machine learning techniques with a focus on fault tolerant quantum error correction in regimes that are relevant to near term experiments It is shown that even in low noise rate regimes and with no knowledge of the noise noise can be further suppressed for small distance codes Limitations of machine learning decoders as well as the classical resources required to perform active error correction are discussed In many cases gate times can be much shorter than typical measurement times of quantum states Further classical decoding of the syndrome information used in quantum error correction to compute recovery operators can also be much slower than gate times For these reasons schemes where error correction can be implemented in a frame known as the Pauli frame have been developed to avoid active error correction In this thesis we generalize previous Pauli frame schemes and show how Clifford frame error correction can be implemented with minimal overhead Clifford frame error correction is necessary if the logical component of recovery operators were chosen from the Clifford group but could also be used in randomized benchmarking schemes

Quantum Error Correction Daniel A. Lidar, Todd A. Brun, 2013-09-12 Focusing on methods for quantum error correction this book is invaluable for graduate students and experts in quantum information science

Quantum Computing N.B. Singh, Quantum Computing is a comprehensive and accessible exploration of one of the most exciting and rapidly evolving fields in modern science Written with both beginners and advanced enthusiasts in mind this book offers a captivating journey through the world of quantum computing without the need for complex mathematical formulas With 50 engaging chapters covering a

wide range of topics readers will discover the fascinating principles behind quantum mechanics and how they are harnessed to revolutionize computing cryptography telecommunications and even our understanding of consciousness and the universe itself From the basics of qubits and superposition to advanced applications like quantum cryptography and artificial intelligence this book presents complex concepts in a clear and easy to understand manner making it suitable for readers of all backgrounds Whether you re a curious novice or a seasoned quantum enthusiast Quantum Computing offers a captivating glimpse into the extraordinary possibilities of the quantum world

The Complexity of Noise Amit Hagar,2022-05-31 In quantum computing where algorithms exist that can solve computational problems more efficiently than any known classical algorithms the elimination of errors that result from external disturbances or from imperfect gates has become the holy grail and a worldwide quest for a large scale fault tolerant and computationally superior quantum computer is currently taking place Optimists rely on the premise that under a certain threshold of errors an arbitrary long fault tolerant quantum computation can be achieved with only moderate i e at most polynomial overhead in computational cost Pessimists on the other hand object that there are in principle as opposed to merely technological reasons why such machines are still inexistent and that no matter what gadgets are used large scale quantum computers will never be computationally superior to classical ones Lacking a complete empirical characterization of quantum noise the debate on the physical possibility of such machines invites philosophical scrutiny Making this debate more precise by suggesting a novel statistical mechanical perspective thereof is the goal of this project

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Quantum Computing Shrikant Tiwari,Amit Kumar Tyagi,S.V. Nagaraj,2025-04-17 Quantum computing and algorithms are set to revolutionize information processing Covering such topics Quantum Computing The Future of Information Processing explains its principles practical applications and future implications in a clear and accessible manner The book strives to simplify the essential concepts and practical applications of quantum computing Its aim is to help students and researchers to apply quantum computing to advance AI and machine learning cybersecurity and blockchain With its emphasis on practical applications the book covers how quantum computing is changing such fields as Finance Medicine Built environment Networking and communications With extensive real world case studies and practical implementation guidance the book is a guide for those seeking to understand how quantum computing is applied in various industries Its in depth exploration of quantum computing covers both foundational principles and advanced applications in a single resource saving readers the need to purchase multiple books Finally the book focuses on the future of information processing so that students and researchers can anticipate and prepare for the transformative impact of quantum computing

Large-scale Simulations of Error Prone Quantum Computation Devices Doan Binh Trieu,2010

Novel Methods in Quantum Error Correction Tomas Jochym-O'Connor,2016 Quantum error correction is the backbone of fault tolerant quantum computation a necessary requirement for any large scale quantum computer The

fault tolerance threshold theorem has long been a target for experimental precision allowing for the possibility of reducing logical error rates to arbitrarily low levels without excessive overhead While there are many promising fault tolerant architectures the path towards the most practical fault tolerant scheme is far from decided and may vary for differing physical models This thesis proposes new schemes for universal fault tolerant quantum computation in both the concatenated and topological code settings Through the concatenation of two different error correcting codes a set of universal fault tolerant gates can be obtained without requiring the need for magic state distillation A lower bound of 1.28×10^3 for the fault tolerance threshold under circuit level depolarizing noise is obtained Additionally stacked codes are proposed as a means to simulate the action of a 3D topological code in 2D allowing for the application of a universal set of transversal operations While fault tolerant unfortunately the scheme does not exhibit a threshold due to the decreasing pseudo threshold with growing code distance yet points to potential interesting avenues for fault tolerant computation in 2D without distillation One of the primary avenues to constructing fault tolerant logical operations is through transversal operations In this thesis the set of single qubit logical gates that can be implemented transversally are characterized and determined to all belong to the Clifford hierarchy Moreover any diagonal two qubit operation that can be applied transversally must belong to the same level of the Clifford hierarchy as the set of gates that can be implemented in the single qubit case The opposite to quantum error correction is privacy where the output of a channel is disguised from its input The two are fundamentally related through the complementary channel construction This thesis presents a new class of private quantum channels expanding the existing class beyond a seemingly fundamental restriction This yields interesting insights into the structure of quantum information and the leaking of information to external environments Additionally the duality is only recovered when extending the complementary channel to sufficiently high environmental dimension Finally the error properties of bucket brigade quantum Random Access Memory qRAM are assessed It is determined that using the bucket brigade qRAM architecture for the running of Grover's algorithm necessitates reducing the error rate of the individual components to exponentially small levels for an exponential sized memory As such fault tolerant architectures will likely play an essential role in the construction of such computing primitives

Quantum Information Processing and Quantum Error Correction
 Ivan B. Djordjevic, 2012-05-23 Quantum Information Processing and Quantum Error Correction is a self contained tutorial based introduction to quantum information quantum computation and quantum error correction Assuming no knowledge of quantum mechanics and written at an intuitive level suitable for the engineer the book gives all the essential principles needed to design and implement quantum electronic and photonic circuits Numerous examples from a wide area of application are given to show how the principles can be implemented in practice This book is ideal for the electronics photonics and computer engineer who requires an easy to understand foundation on the principles of quantum information processing and quantum error correction together with insight into how to develop quantum electronic and photonic circuits

Readers of this book will be ready for further study in this area and will be prepared to perform independent research. The reader who completed the book will be able to design the information processing circuits, stabilizer codes, Calderbank-Shor-Steane (CSS) codes, subsystem codes, topological codes, and entanglement-assisted quantum error correction codes, and propose corresponding physical implementations. The reader who completed the book will be proficient in quantum fault-tolerant design as well. Unique Features: Unique in covering both quantum information processing and quantum error correction, everything in one book that an engineer needs to understand and implement quantum level circuits. Gives an intuitive understanding by not assuming knowledge of quantum mechanics, thereby avoiding heavy mathematics. In-depth coverage of the design and implementation of quantum information processing and quantum error correction circuits. Provides the right balance among the quantum mechanics, quantum error correction, quantum computing, and quantum communication. Dr. Djordjevic is an Assistant Professor in the Department of Electrical and Computer Engineering of the College of Engineering, University of Arizona, with a joint appointment in the College of Optical Sciences. Prior to this appointment in August 2006, he was with the University of Arizona, Tucson, USA, as a Research Assistant Professor; the University of the West of England, Bristol, UK; the University of Bristol, Bristol, UK; Tyco Telecommunications, Eatontown, USA; and the National Technical University of Athens, Athens, Greece. His current research interests include optical networks, error control coding, constrained coding, coded modulation, turbo equalization, OFDM applications, and quantum error correction. He presently directs the Optical Communications Systems Laboratory (OCSL) within the ECE Department at the University of Arizona. Provides everything an engineer needs in one tutorial-based introduction to understand and implement quantum level circuits. Avoids the heavy use of mathematics by not assuming the previous knowledge of quantum mechanics. Provides in-depth coverage of the design and implementation of quantum information processing and quantum error correction circuits.

Quantum Error Correction And Fault Tolerant Quantum Computing Book Review: Unveiling the Magic of Language

In an electronic digital era where connections and knowledge reign supreme, the enchanting power of language has are more apparent than ever. Its capability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Quantum Error Correction And Fault Tolerant Quantum Computing**," written by a very acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound effect on our existence. Throughout this critique, we will delve to the book is central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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