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Quantum Error Correction Lectures on Quantum Computation, Quantum Error Correcting Codes and Information Theory Quantum Error Correction and Fault Tolerant Quantum Computing Entanglement and Quantum Error Correction with Superconducting Qubits Good Additive Cyclic Quantum Error-correcting Codes Quantum Information Processing and Quantum Error Correction Quantum Error Correction Codes Quantum Error Correction Calculations of Quantum Error Correction and Fault Tolerance Thresholds Topological Quantum Error-Correcting Codes Beyond Dimension 2 Quantum Error-correcting Codes Device- and Application-adapted Quantum Error Correction Quantum Error Correction Quantum Error Correction for General Noise Benchmarking Quantum Error-correcting Codes on Quasi-linear and Central-spin Processors The Complexity of Noise Quantum Error-correcting Codes and Devices Quantum Error Correcting Code Simulation Quantum Error Correction Quantum Error Correction and Spacetime Quantum Error Correcting Codes Elements of Quantum Error Correction A Thesis on Quantum Error Correction and Leakage Elimination for Quantum Dots Analysis of Quantum Error-correcting Codes Operator Quantum Error Correction Quantum Information Processing, Quantum Computing, and Quantum Error Correction Quantum Error Correction - Decoders Quantum Error Correction and Fault Tolerant Quantum Computing - S The Effects of Quantum Error Correction on Noisy Systems Channel-adapted Quantum Error Correction Optical Implementations of Quantum Error Correction Codes Linear Programming Bounds for Maximal Entanglement-Assisted Quantum Error-Correcting Codes Quantum error correction (QEC) Quantum Error Correction for Noisy Quantum Channels in Optical Coherent State Quantum Information Processing Quantum Error Correction with Biased Noise Operator Quantum Error Correction and Quantum Statistical Inference Homological Quantum Error Correcting Codes and Systolic Freedom Stabilizer Formalism for Quantum Error Correction and Its Subsystem Generalization Novel Methods in Quantum Error Correction Non-Gaussian Methods for Quantum Error Correction

Quantum Error Correction *2013-09-12*

QUANTUM COMPUTATION AND INFORMATION IS ONE OF THE MOST EXCITING DEVELOPMENTS IN SCIENCE AND TECHNOLOGY OF THE LAST TWENTY YEARS TO ACHIEVE LARGE SCALE QUANTUM COMPUTERS AND COMMUNICATION NETWORKS IT IS ESSENTIAL NOT ONLY TO OVERCOME NOISE IN STORED QUANTUM INFORMATION BUT ALSO IN GENERAL FAULTY QUANTUM OPERATIONS SCALABLE QUANTUM COMPUTERS REQUIRE A FAR REACHING THEORY OF FAULT TOLERANT QUANTUM COMPUTATION THIS COMPREHENSIVE TEXT WRITTEN BY LEADING EXPERTS IN THE FIELD FOCUSES ON QUANTUM ERROR CORRECTION AND THOROUGHLY COVERS THE THEORY AS WELL AS EXPERIMENTAL AND PRACTICAL ISSUES THE BOOK IS NOT LIMITED TO A SINGLE APPROACH BUT REVIEWS MANY DIFFERENT METHODS TO CONTROL QUANTUM ERRORS INCLUDING TOPOLOGICAL CODES DYNAMICAL DECOUPLING AND DECOHERENCE FREE SUBSPACES BASIC SUBJECTS AS WELL AS ADVANCED THEORY AND A SURVEY OF TOPICS FROM CUTTING EDGE RESEARCH MAKE THIS BOOK INVALUABLE BOTH AS A PEDAGOGICAL INTRODUCTION AT THE GRADUATE LEVEL AND AS A REFERENCE FOR EXPERTS IN QUANTUM INFORMATION SCIENCE

Lectures on Quantum Computation, Quantum Error Correcting Codes and Information Theory *2006*

THESE NOTES ARE BASED ON A COURSE OF ABOUT TWENTY LECTURES ON QUANTUM COMPUTATION QUANTUM ERROR CORRECTING CODES AND INFORMATION THEORY THE TOPICS INCLUDE A COMPARATIVE DESCRIPTION OF THE BASIC FEATURES OF CLASSICAL PROBABILITY THEORY ON FINITE SAMPLE SPACES AND QUANTUM PROBABILITY THEORY ON FINITE DIMENSIONAL COMPLEX HILBERT SPACES QUANTUM GATES AND CICUITS SIMPLE EXAMPLES OF CIRCUITS ARISING FROM QUANTUM TELEPORTATION COMMUNICATION THROUGH EPR PAIRS AND ARITHMETICAL COMPUTATIONS ON A QUANTUM COMPUTER MORE SOPHISTICATED EXAMPLES OF SUCH CIRCUITS IN THE CONTEXT OF FOURIER TRANSFORM AND PHASE ESTIMATION A DETAILED ACCOUNT OF THE ORDER FINDING ALGORITHM AS WELL AS THE CELEBRATED SHOR S ALGORITHM FOR FACTORISING A POSITIVE INTEGER INTO ITS PRIME FACTORS THERE IS A LEISURELY DISCUSSION OF QUANTUM ERROR CORRECTING CODES WITH THE KNILL LAFLAMME CRITERION FOR ERROR CORRECTION AND A NUMBER OF EXAMPLES OF SUCH CODES WHOSE CONSTRUCTION IS BASED ON THE WEYL COMMUTATION RELATIONS FOR FINITE ABELIAN GROUPS THE READER MAY FIND HERE A BRIEF INTRODUCTION TO THE BASIC IDEAS OF CLASSICAL INFORMATION THEORY AS DEVELOPED BY SHANNON PROPERTIES OF VON NEUMANN S QUANTUM ENTROPY AND RELATIVE ENTROPY AS WELL AS A PROOF OF SCHUMACHER S NOISELESS QUANTUM CODING THEOREM THE HOLEVO BOUND FOR TRANSMISSION OF CLASSICAL INFORMATION THROUGH ENCODING BY QUANTUM STATES FOLLOWED BY MEASUREMENTS IS DERIVED THE ONLY BACKGROUND ASSUMED OF THE READER IS LINEAR ALGEBRA ON FINITE DIMENSIONAL COMPLEX VECTOR SPACES AND ELEMENTARY CLASSICAL PROBABILITY THEORY ON FINITE SAMPLE SPACES THESE NOTES ARE AIMED AT MATHEMATICIANS AND COMPUTER SCIENTISTS WHO ARE CURIOUS TO KNOW THE MYSTERY BEHIND A QUANTUM COMPUTER AND THE POSSIBILITY OF COMMUNICATING INFORMATION USING THE PRINCIPLES OF ELEMENTARY QUANTUM THEORY

Quantum Error Correction and Fault Tolerant Quantum Computing *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

Entanglement and Quantum Error Correction with Superconducting Qubits 2013

SOFTCOVER VERSION OF 2013 PH D THESIS OF MATTHEW DAVID REED PRESENTED TO THE PHYSICS DEPARTMENT OF YALE UNIVERSITY CONCERNS THE REALIZATION OF QUANTUM ERROR CORRECTION IN THE CIRCUIT QUANTUM ELECTRODYNAMICS ARCHITECTURE A PRECURSOR TO QUANTUM COMPUTING

Good Additive Cyclic Quantum Error-correcting Codes *2004*

THIS THESIS IS ABOUT THE QUANTUM ERROR CORRECTING CODES ALTHOUGH THERE ARE MANY METHODS TO CONSTRUCT THEM FINDING A GOOD QUANTUM CODE IS STILL A COMPLICATED AND DIFFICULT TASK FOR WE DO NOT KNOW WHICH METHODS TO USE TO SOLVE THIS PROBLEM WE DID A THOROUGH RESEARCH ON A SPECIAL CLASS OF QUANTUM CODES ADDITIVE CYCLIC QUANTUM CODES A NEW SEARCH ALGORITHM HAS BEEN DESIGNED AND A LOT OF GOOD ADDITIVE CYCLIC QUANTUM CODES FOUND BY THIS ALGORITHM ARE PRESENTED IN THIS THESIS BY SHOWING THE SUCCESS OF THIS ALGORITHM AND GREAT VALUE OF ADDITIVE CYCLIC QUANTUM CODES WE HAVE GREATLY REDUCED THE COMPLEXITY OF FINDING GOOD QUANTUM CODES QUANTUM ERROR CORRECTION THEORY IS KEY PART OF QUANTUM INFORMATION THEORY AS QUANTUM INFORMATION THEORY IS A QUITE NEW FIELD WHICH HAS BEEN DEVELOPING FAST DURING THE LAST DECADE WE SPENT MUCH TIME EXPLAINING THE PRIMARY CONCEPTS OF IT WE INTRODUCED LINEAR ALGEBRA QUANTUM MECHANICS QUANTUM OPERATIONS QUANTUM ERROR CORRECTION THEORY AND QUANTUM ERROR CORRECTING CODES IN A WORD THIS THESIS SERVES TWO FUNCTIONS 1 AN EXPLORATION OF QUANTUM ERROR CORRECTING CODES AND 2 AN INTRODUCTION TO QUANTUM INFORMATION THEORY

Quantum Information Processing and Quantum Error Correction *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 COMPLETED THE BOOK WILL BE ABLE 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 IMPLEMENTATION THE READER 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 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 UNIVERSITY OF ARIZONA TUCSON USA AS A RESEARCH ASSISTANT PROFESSOR UNIVERSITY OF THE WEST OF ENGLAND BRISTOL UK UNIVERSITY OF BRISTOL BRISTOL UK TYCO TELECOMMUNICATIONS EATONTOWN USA AND 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 Codes 2015

THIS TEXT PRESENTS AN ALGEBRAIC APPROACH TO THE CONSTRUCTION OF SEVERAL IMPORTANT FAMILIES OF QUANTUM CODES DERIVED FROM CLASSICAL CODES BY APPLYING THE WELL KNOWN CALDERBANK SHOR STEANE CSS HERMITIAN AND STEANE ENLARGEMENT CONSTRUCTIONS TO CERTAIN CLASSES OF CLASSICAL CODES IN ADDITION THE BOOK PRESENTS FAMILIES OF ASYMMETRIC QUANTUM CODES WITH GOOD PARAMETERS AND PROVIDES A DETAILED DESCRIPTION OF THE PROCEDURES ADOPTED TO CONSTRUCT FAMILIES OF ASYMMETRIC QUANTUM CONVOLUTIONAL CODES FEATURING ACCESSIBLE LANGUAGE AND CLEAR EXPLANATIONS THE BOOK IS SUITABLE FOR USE IN ADVANCED UNDERGRADUATE AND GRADUATE COURSES AS WELL AS FOR SELF GUIDED STUDY AND REFERENCE IT PROVIDES AN EXPERT INTRODUCTION TO ALGEBRAIC TECHNIQUES OF CODE CONSTRUCTION AND BECAUSE ALL OF THE CONSTRUCTIONS ARE PERFORMED ALGEBRAICALLY IT ENABLES THE READER TO CONSTRUCT FAMILIES OF CODES RATHER THAN ONLY CODES WITH SPECIFIC PARAMETERS THE TEXT OFFERS AN ABUNDANCE OF WORKED EXAMPLES EXERCISES AND OPEN ENDED PROBLEMS TO MOTIVATE THE READER TO FURTHER INVESTIGATE THIS RICH AREA OF INQUIRY END OF CHAPTER SUMMARIES AND A GLOSSARY OF KEY TERMS ALLOW FOR EASY REVIEW AND REFERENCE

Quantum Error Correction 2020-06-25

ERROR CORRECTION IS THE SET OF TECHNIQUES USED IN ORDER TO STORE PROCESS AND TRANSMIT INFORMATION RELIABLY IN A NOISY CONTEXT THE CLASSICAL THEORY OF ERROR CORRECTION IS BASED ON ENCODING CLASSICAL INFORMATION REDUNDANTLY A MAJOR ENDEAVOR OF THE THEORY IS TO FIND OPTIMAL TRADE OFFS BETWEEN REDUNDANCY WHICH WE TRY TO MINIMIZE AND NOISE TOLERANCE WHICH WE TRY TO MAXIMIZE THE QUANTUM THEORY OF ERROR CORRECTION CANNOT DIRECTLY IMITATE THE REDUNDANT SCHEMES OF THE CLASSICAL THEORY BECAUSE IT HAS TO COPE WITH THE NO CLONING THEOREM QUANTUM INFORMATION CANNOT BE COPIED QUANTUM ERROR CORRECTION IS NONETHELESS POSSIBLE BY SPREADING THE INFORMATION ON MORE QUANTUM MEMORY ELEMENTS THAN WOULD BE NECESSARY IN QUANTUM INFORMATION THEORY DILUTION OF THE INFORMATION REPLACES REDUNDANCY SINCE COPYING IS FORBIDDEN BY THE LAWS OF QUANTUM MECHANICS BESIDES THIS CONCEPTUAL DIFFERENCE QUANTUM ERROR CORRECTION INHERITS A LOT FROM ITS CLASSICAL COUNTERPART IN THIS PHD THESIS WE ARE CONCERNED WITH A CLASS OF QUANTUM ERROR CORRECTING CODES WHOSE CLASSICAL COUNTERPART WAS DEFINED IN 1961 BY GALLAGER GAL62 AT THAT TIME QUANTUM INFORMATION WAS NOT EVEN A RESEARCH DOMAIN YET THIS CLASS IS THE FAMILY OF LOW DENSITY PARITY CHECK LDPC CODES INFORMALLY A CODE IS SAID TO BE LDPC IF THE CONSTRAINTS IMPOSED TO ENSURE REDUNDANCY IN THE CLASSICAL SETTING OR DILUTION IN THE QUANTUM SETTING ARE LOCAL MORE PRECISELY THIS PHD THESIS FOCUSES ON A SUBSET OF THE LDPC QUANTUM ERROR CORRECTING CODES THE HOMOLOGICAL QUANTUM ERROR CORRECTING CODES THESE CODES TAKE THEIR NAME FROM THE MATHEMATICAL FIELD OF HOMOLOGY WHOSE OBJECTS OF STUDY ARE SEQUENCES OF LINEAR MAPS SUCH THAT THE KERNEL OF A MAP CONTAINS THE IMAGE OF ITS LEFT NEIGHBOUR ORIGINALLY INTRODUCED TO STUDY THE TOPOLOGY OF GEOMETRIC SHAPES HOMOLOGY THEORY NOW ENCOMPASSES MORE ALGEBRAIC BRANCHES AS WELL WHERE THE FOCUS IS MORE ABSTRACT AND COMBINATORIAL THE SAME IS TRUE OF HOMOLOGICAL CODES THEY WERE INTRODUCED IN 1997 BY KITAEV KIT03 WITH A QUANTUM CODE THAT HAS THE SHAPE OF A TORUS THEY NOW FORM A VAST FAMILY OF QUANTUM LDPC CODES SOME MORE INSPIRED FROM GEOMETRY THAN OTHERS HOMOLOGICAL QUANTUM CODES WERE DESIGNED FROM SPHERICAL EUCLIDEAN AND HYPERBOLIC GEOMETRIES FROM 2 DIMENSIONAL 3 DIMENSIONAL AND 4 DIMENSIONAL OBJECTS FROM OBJECTS WITH INCREASING AND UNBOUNDED DIMENSION AND FROM HYPERGRAPH OR HOMOLOGICAL PRODUCTS AFTER INTRODUCING SOME GENERAL QUANTUM INFORMATION CONCEPTS IN THE FIRST CHAPTER OF THIS MANUSCRIPT WE FOCUS IN THE TWO FOLLOWING ONES ON FAMILIES OF QUANTUM CODES BASED ON 4 DIMENSIONAL HYPERBOLIC OBJECTS WE HIGHLIGHT THE INTERPLAY BETWEEN THEIR GEOMETRIC SIDE GIVEN BY MANIFOLDS AND THEIR COMBINATORIAL SIDE GIVEN BY ABSTRACT POLYTOPES WE USE BOTH SIDES TO ANALYZE THE CORRESPONDING QUANTUM CODES IN THE FOURTH AND LAST CHAPTER WE ANALYZE A FAMILY OF QUANTUM CODES BASED ON SPHERICAL OBJECTS OF ARBITRARY DIMENSION TO HAVE MORE FLEXIBILITY IN THE DESIGN OF QUANTUM CODES WE USE COMBINATORIAL OBJECTS THAT REALIZE THIS SPHERICAL GEOMETRY HYPERCUBE COMPLEXES THIS SETTING ALLOWS US TO INTRODUCE A NEW LINK BETWEEN CLASSICAL AND QUANTUM ERROR CORRECTION WHERE CLASSICAL CODES ARE USED TO INTRODUCE HOMOLOGY IN HYPERCUBE COMPLEXES

Calculations of Quantum Error Correction and Fault Tolerance Thresholds 2008

PRECISE CONTROL OF COHERENT QUANTUM SYSTEMS COULD ENABLE NEW GENERATIONS OF SENSING COMMUNICATION AND COMPUTING TECHNOLOGIES SUCH SYSTEMS HOWEVER ARE TYPICALLY NOISY AND DIFFICULT TO STABILIZE ONE PROMISING TECHNIQUE TO THIS END IS CALLED QUANTUM ERROR CORRECTION WHICH ENCODES QUANTUM STATES IN SUCH A WAY THAT ERRORS CAN BE DETECTED AND CORRECTED MUCH LIKE IN CLASSICAL ERROR CORRECTING CODES QUANTUM ERROR CORRECTING CODES USUALLY CAST A WIDE NET IN THAT THEY ARE DESIGNED TO CORRECT ERRORS REGARDLESS OF THEIR PHYSICAL ORIGINS IN LARGE SCALE DEVICES THIS IS AN ESSENTIAL FEATURE IT COMES AT A COST HOWEVER CONVENTIONAL QUANTUM CODES ARE TYPICALLY RESOURCE INTENSIVE IN TERMS OF BOTH THE SYSTEM SIZE AND THE CONTROL OPERATIONS THEY REQUIRE YET IN SMALLER SCALE DEVICES THE MAIN ERROR SOURCES ARE OFTEN WELL UNDERSTOOD IN THE NEAR TERM IT MAY THEREFORE BE ADVANTAGEOUS TO CAST A MORE TARGETED NET THROUGH SPECIALIZED CODES THIS THESIS PRESENTS NEW FAMILIES OF SUCH QUANTUM ERROR CORRECTING CODES WHICH ARE ADAPTED EITHER FOR LEADING CANDIDATE DEVICES OR FOR NEAR TERM APPLICATIONS THE DEVICE ADAPTED CODES REQUIRE EXPONENTIALLY LESS OVERHEAD THAN CONVENTIONAL CODES TO ACHIEVE THE SAME LEVEL OF PROTECTION WHEREAS THE APPLICATION ADAPTED CODES CAN ENHANCE QUANTUM SENSORS IN WHICH CONVENTIONAL CODES CANNOT READILY BE USED THE NEW TECHNIQUES PRESENTED IN THIS THESIS ADAPT CORNERSTONES OF CONVENTIONAL THEORY IN LIGHT OF KEY EXPERIMENTAL CHALLENGES AND OPPORTUNITIES THE ULTIMATE GOAL OF THIS RESEARCH IS TO HELP BRIDGE THE GAP BETWEEN THE EXACTING REQUIREMENTS OF PROPOSED QUANTUM TECHNOLOGIES AND THE REALITIES OF EMERGING QUANTUM DEVICES BRIDGING THIS GAP IS CRITICAL IF QUANTUM TECHNOLOGIES ARE TO REALIZE THEIR FULL POTENTIAL

Topological Quantum Error-Correcting Codes Beyond Dimension 2 *2019*

large quantum computers have the potential to vastly outperform any classical computer the biggest obstacle to building quantum computers of such size is noise for example state of the art superconducting quantum computers have average decoherence loss of information times of just microseconds thus the field of quantum error correction is especially crucial to progress in the development of quantum technologies in this research we study quantum error correction for general noise which is given by a linear hermitian map in standard quantum error correction the usual assumption is to constrain the errors to completely positive maps which is a special case of linear hermitian maps we establish constraints and sufficient conditions for the possible error correcting codes that can be used for linear hermitian maps afterwards we expand these sufficient conditions to cover a large class of general errors these conditions lead to currently known conditions in the limit that the error map becomes completely positive the later chapters give general results for quantum evolution maps a set of weak repeated projective measurements that never break entanglement and the asymmetric depolarizing map composed with a not completely positive map that gives a completely positive composition finally we give examples

Quantum Error-correcting Codes 2004

quantum computers are hypothetical quantum information processing qip devices that allow one to store manipulate and extract information while harnessing quantum physics to solve various computational problems and do so putatively more efficiently than any known classical counterpart 5 physical objects as they are qip devices are subject to the laws of physics no doubt the application of these laws is error free but noise be it external influences or hardware imprecisions can sometimes cause a mismatch between what the qip device is supposed to do and what it actually does in recent years the elimination of noise that result from external disturbances or from imperfect gates has become the holy grail within the quantum computing community and a worldwide quest for a large scale fault tolerant and computationally superior qip device is currently taking place whether such machines are possible is an exciting open question yet the debate on their feasibility has been so far rather ideological in character 45 66 110 162 remarkably philosophers of science have been mostly silent about it common wisdom has it that philosophy should not intervene in what appears to be and is also presented as an engineering problem and besides the mathematics employed in the theory of fault tolerant quantum error correction ftqec henceforth is rather daunting it turns out however that behind this technical veil the central issues at the heart of the debate are worthy of philosophical analysis and moreover bear strong similarities to the conceptual problems that have been saturating a field quite familiar to philosophers namely the foundations of statistical mechanics sm henceforth reconstructing the debate on ftqec with statistical mechanical analogies this book aims to introduce it to readership outside the quantum computing community and to take preliminary steps towards making it less ideological and mor

Device- and Application-adapted Quantum Error Correction *2020*

a method of forming quantum error correcting codes by first forming a stabilizer for a hilbert space a quantum information processing device can be formed to implement such quantum codes

Quantum Error Correction *1998*

quantum error correction qec is a branch of quantum information theory originally invented to protect hypothetical quantum computers against realistic sources of noise qec has enjoyed significant success within the paradigm of computation but the ideas and techniques of quantum error correction have also been effective in tools many fields of physics in this thesis we will shed light on the way in which qec manifests outside of the usual computational paradigm and informs other areas of physics we ll focus on the role of qec in quantum gravity spacetime and high energy theoretical physics we start with the general problem of quantum information replication in spacetime and we show that information replication is possible if and only if transmission of the quantum information does not result in cloning of quantum information or faster than light communication we then study the role of quantum error correction in quantum gravity specifically within a gauge gravity duality known as ads cft we establish a new formula for mapping observables on either side of the duality showing that the so called bulk to boundary map defines an approximate quantum error correcting code motivated by the study of entangled states dual to multi boundary wormholes in ads cft we then turn our attention to characterizing the states that can arise from the euclidean path integral in three dimensional chern simons theories we study u 1 level k and so 3 level k chern simons theories on euclidean 3 manifolds with torus boundaries for the abelian u 1 theory we find that the set of states that can be prepared exactly coincides with the set of stabilizer states which are characterized by quantum error correcting codes for the non abelian so 3 theory we find that any state can be prepared to arbitrary precision giving rise to a notion of state universality we conclude with some final observations to support the idea that entanglement gives rise to the connectedness of spacetime we study the partial transpose of the thermofield double tfd state geometrically and we demonstrate that local time reversal which is unitarily equivalent to partial transpose leads to inconsistencies in the connected spacetime dual to the tfd state

Quantum Error Correction for General Noise *2021*

the development of a quantum computer presents one of the greatest challenges in science and engineering to date the promise of more efficient computing based on entangled quantum states and the superposition principle has led to a worldwide explosion of interest in the fields of quantum information and computation decoherence is one of the main problems that gives rise to different errors in the quantum system however the discovery of quantum error correction and the establishment of the accuracy threshold theorem provide us comprehensive tools to build a quantum computer this thesis contributes to this effort by investigating a particular class of quantum error correcting codes called decoherence free subsystems the passive approach to error correction taken by these encodings provides an efficient means of protection for symmetrically coupled system bath interactions here i will present methods for determining the subsystem preserving evolutions for noiseless subsystem encodings and more importantly implementing a universal quantum computing over three quantum dots

Benchmarking Quantum Error-correcting Codes on Quasi-linear and Central-spin Processors 2023

the second edition of quantum information processing quantum computing and quantum error correction an engineering approach presents a self contained introduction to all aspects of the area teaching the essentials such as state vectors

OPERATORS DENSITY OPERATORS MEASUREMENTS AND DYNAMICS OF A QUANTUM SYSTEM IN ADDITIONAL TO THE FUNDAMENTAL PRINCIPLES OF QUANTUM COMPUTATION BASIC QUANTUM GATES BASIC QUANTUM ALGORITHMS AND QUANTUM INFORMATION PROCESSING THIS EDITION HAS BEEN BROUGHT FULLY UP TO DATE OUTLINING THE LATEST RESEARCH TRENDS THESE INCLUDE KEY TOPICS INCLUDE QUANTUM ERROR CORRECTION CODES QECCS INCLUDING STABILIZER CODES CALDERBANK SHOR STEANE CSS CODES QUANTUM LOW DENSITY PARITY CHECK LDPC CODES ENTANGLEMENT ASSISTED QECCS TOPOLOGICAL CODES AND SURFACE CODES QUANTUM INFORMATION THEORY AND QUANTUM KEY DISTRIBUTION QKD FAULT TOLERANT INFORMATION PROCESSING AND FAULT TOLERANT QUANTUM ERROR CORRECTION TOGETHER WITH A CHAPTER ON QUANTUM MACHINE LEARNING BOTH QUANTUM CIRCUITS AND MEASUREMENT BASED QUANTUM COMPUTATIONAL MODELS ARE DESCRIBED THE NEXT PART OF THE BOOK IS SPENT INVESTIGATING PHYSICAL REALIZATIONS OF QUANTUM COMPUTERS ENCODERS AND DECODERS INCLUDING PHOTONIC QUANTUM REALIZATION CAVITY QUANTUM ELECTRODYNAMICS AND ION TRAPS IN DEPTH ANALYSIS OF THE DESIGN AND REALIZATION OF A QUANTUM INFORMATION PROCESSING AND QUANTUM ERROR CORRECTION CIRCUITS THIS FULLY UP TO DATE NEW EDITION WILL BE OF USE TO ENGINEERS COMPUTER SCIENTISTS OPTICAL ENGINEERS PHYSICISTS AND MATHEMATICIANS A SELF CONTAINED INTRODUCTION TO QUANTUM INFORMATION PROCESSING AND QUANTUM ERROR CORRECTION INTEGRATES QUANTUM INFORMATION PROCESSING QUANTUM COMPUTING AND QUANTUM ERROR CORRECTION DESCRIBES THE LATEST TRENDS IN THE QUANTUM INFORMATION PROCESSING QUANTUM ERROR CORRECTION AND QUANTUM COMPUTING PRESENTS THE BASIC CONCEPTS OF QUANTUM MECHANICS IN DEPTH PRESENTATION OF THE DESIGN AND REALIZATION OF A QUANTUM INFORMATION PROCESSING AND QUANTUM ERROR CORRECTION CIRCUIT

The Complexity of Noise 2010

ERROR CORRECTION IS USED TO CORRECT ANY ERRORS THAT MAY ARISE WHEN SENDING ANY MESSAGE AS ERRORS ARE PRONE TO APPEAR DUE TO NOISE FOR CLASSICAL CODES THERE ARE MANY DECODERS USED FOR EXAMPLE BELIEF PROPAGATION UNFORTUNATELY THESE CLASSICAL DECODERS ARE LESS EFFICIENT FOR QUANTUM CODES A PROPOSED REMEDY TO IMPROVE THE DECODERS EFFICIENCY IS TO USE A NEURAL NETWORK FOR DECODING IN THIS THESIS WE WILL IMPLEMENT BELIEF PROPAGATION ON THE TORIC CODE AND CHECK ITS EFFICIENCY WE WILL SEE THAT FOR FEW ERRORS BELIEF PROPAGATION WORKS BUT IT FAILS FOR OTHER CASES WE ALSO INTRODUCE THE MODIFICATIONS NEEDED FOR NEURAL BELIEF PROPAGATION A MODIFICATION OF THE ORIGINAL ALGORITHM THAT INTEGRATES A NEURAL NETWORK ON THE ALGORITHM STRUCTURE

Quantum Error-correcting Codes and Devices 2000

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 Correcting Code Simulation *2015*

FULL ACCURACY SIMULATIONS OF QUANTUM SYSTEMS ARE VERY COSTLY AND AS A RESULT MOST STUDIES OF QUANTUM ERROR CORRECTION ASSUME A PROBABILISTIC PAULI ERROR MODEL LARGELY BECAUSE SUCH ERRORS CAN BE E CIENTLY SIMULATED THEREFORE THE BEHAVIOUR OF MORE GENERAL NOISE IN A QUANTUM ERROR CORRECTING CODE IS POORLY CHARACTERIZED IN THIS THESIS WE PRESENT RESULTS WHICH DEMONSTRATE THE SCALING OF THE LOGICAL NOISE WITH RESPECT TO THE PHYSICAL DELITY AND ARGUE THAT THE E ECTIVE LOGICAL NOISE APPROACHES A PAULI CHANNEL AS THE CODE DISTANCE INCREASES EVEN WHEN NO RECOVERY OPERATIONS ARE APPLIED AS A RESULT WE ARGUE THAT THE AVERAGE LOGICAL DELITY CAN BE USED TO ACCURATELY QUANTIFY THE E ECTIVE LOGICAL NOISE AND TO SELECT RECOVERY OPERATIONS APPROPRIATE TO THE SYSTEM WE FURTHER DEMONSTRATE THAT WHEN PHYSICAL NOISE ACTS ON FEWER THAN D QUBITS IN AN N K D CODE THE RESULTANT NOISE IS PAULI AND DEVELOP A METHOD FOR APPROXIMATING THE DOMINANT CONTRIBUTIONS TO THE E ECTIVE LOGICAL NOISE UP TO A SPECI ED PRECISION IN TERMS OF THE PHYSICAL IN DELITY WE DERIVE CONDITIONS UNDER WHICH SETS OF RECOVERY OPERATIONS WILL PRODUCE EQUIVALENT LOGICAL NOISE CHANNELS WITH EXAMPLES OF EQUIVALENCIES IN THE 3 QUBIT REPETITION CODE THE 5 QUBIT CODE THE STEANE CODE AND THE SHOR CODE WE ALSO PROVIDE A GENERAL EXPRESSION FOR THE E ECTIVE LOGICAL NOISE WHEN THE PHYSICAL QUBITS UNDERGO DEPOLARIZING OR PAULI NOISE IN A QUANTUM ERROR CORRECTING CODE EXAMINE THE BEHAVIOUR OF DEPOLARIZING NOISE UNDER CONCATENATION OF THE 5 QUBIT AND STEANE CODES AND PRESENT AN ALGORITHM FOR SOFT DECODING WHICH IS NOT SUBJECT TO STATISTICAL SAMPLING WITH AN EMPHASIS ON THE E ECTIVE BEHAVIOUR OF A CONCATENATED 5 QUBIT CODE UNDERGOING DEPOLARIZING NOISE AFTER APPLYING A SPECIALIZED VERSION OUR SOFT DECODING ALGORITHM

Quantum Error Correction *2016*

CONT THESE STRUCTURED OPERATIONS ARE MORE COMPUTATIONALLY SCALABLE THAN THE SDP REQUIRED FOR COMPUTING THE OPTIMAL WE CAN THUS NUMERICALLY ANALYZE LONGER CODES USING LAGRANGE DUALITY WE BOUND THE PERFORMANCE OF THE STRUCTURED RECOVERY OPERATIONS AND SHOW THAT THEY ARE NEARLY OPTIMAL IN MANY RELEVANT CASES WE PRESENT TWO CLASSES OF CHANNEL ADAPTED QUANTUM ERROR CORRECTING CODES SPECIFICALLY DESIGNED FOR THE AMPLITUDE DAMPING CHANNEL THESE HAVE SIGNIFICANTLY HIGHER RATES WITH SHORTER BLOCK LENGTHS THAN CORRESPONDING GENERIC QUANTUM ERROR CORRECTING CODES BOTH CLASSES ARE STABILIZER CODES AND HAVE GOOD FIDELITY PERFORMANCE WITH STABILIZER RECOVERY OPERATIONS THE ENCODING SYNDROME MEASUREMENT AND SYNDROME RECOVERY OPERATIONS CAN ALL BE IMPLEMENTED WITH CLIFFORD GROUP OPERATIONS

Quantum Error Correction and Spacetime *2018*

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 TIMES 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

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