# Applied Coding And Information Theory For Engineers

This textbook serves as an introduction to fault-tolerance, intended for upper-division undergraduate students, graduate-level students and practicing engineers in need of an overview of the field. Readers will develop skills in modeling and evaluating fault-tolerant architectures in terms of reliability, availability and safety. They will gain a thorough understanding of fault tolerant computers, including both the theory of how to design and evaluate them and the practical knowledge of achieving fault-tolerance in electronic, communication and software systems. Coverage includes fault-tolerance techniques through hardware, software, information and time redundancy. The content is designed to be highly accessible, including numerous examples and exercises. Solutions and powerpoint slides are available for instructors.

oW should coded communication be approached? Is it about prob H ability theorems and bounds, or about algorithms and structures? The traditional course in information theory and coding teaches these together in one course in which the Shannon theory, a probabilistic the ory of information, dominates. The theory's predictions and bounds to performance are valuable to the coding engineer, but coding today is mostly about structures and algorithms and their size, speed and error performance. While coding has a theoretical basis, it has a practical side as well, an engineering side in which costs and benefits matter. It is safe to say that most of

the recent advances in information theory and coding are in the engineering of coding. These thoughts motivate the present text book: A coded communication book based on methods and algorithms, with information theory in a necessary but supporting role. There has been muchrecent progress in coding, both inthe theory and the practice, and these pages report many new advances. Chapter 2 cov ers traditional source coding, but also the coding ofreal one-dimensional sources like speech and new techniques like vector quantization. Chapter 4 is a unified treatment of trellis codes, beginning with binary convolu tional codes and passing to the new trellis modulation codes.

Graduate-level study for engineering students presents elements of modern probability theory, elements of information theory with emphasis on its basic roots in probability theory and elements of coding theory. Emphasis is on such basic concepts as sets, sample space, random variables, information measure, and capacity. Many reference tables and extensive bibliography. 1961 edition.

With computers becoming embedded as controllers in everything fromnetwork servers to the routing of subway schedules to NASAmissions, there is a critical need to ensure that systems continueto function even when a component fails. In this book, bestsellingauthor Martin Shooman draws on his expertise in reliabilityengineering and software engineering to provide a complete andauthoritative look at fault tolerant computing. He clearly explainsall fundamentals, including how to use redundant elements in systemdesign to ensure the

reliability of computer systems andnetworks. Market: Systems and Networking Engineers, Computer Programmers, ITProfessionals.

Coding theory came into existence in the late 1940's and is concerned with devising efficient encoding and decoding procedures. The book is intended as a principal text for first courses in coding and algebraic coding theory, and is aimed at advanced undergraduates and recent graduates as both a course and self-study text. BCH and cyclic, Group codes, Hamming codes, polynomial as well as many other codes are introduced in this textbook. Incorporating numerous worked examples and complete logical proofs, it is an ideal introduction to the fundamental of algebraic coding.

This volume is dedicated to the memory of Rudolf Ahlswede, who passed away in December 2010. The Festschrift contains 36 thoroughly refereed research papers from a memorial symposium, which took place in July 2011. The four macro-topics of this workshop: theory of games and strategic planning; combinatorial group testing and database mining; computational biology and string matching; information coding and spreading and patrolling on networks; provide a comprehensive picture of the vision Rudolf Ahlswede put forward of a broad and systematic theory of search.

This graduate textbook provides a unified view of quantum information theory. Clearly explaining the necessary mathematical basis, it merges key topics from both information-theoretic and quantum- mechanical viewpoints and provides lucid explanations of the basic results. Thanks to this unified approach, it makes

accessible such advanced topics in quantum communication as quantum teleportation, superdense coding, quantum state transmission (quantum error-correction) and quantum encryption. Since the publication of the preceding book Quantum Information: An Introduction, there have been tremendous strides in the field of quantum information. In particular, the following topics – all of which are addressed here – made seen major advances: quantum state discrimination, quantum channel capacity, bipartite and multipartite entanglement, security analysis on quantum communication, reverse Shannon theorem and uncertainty relation. With regard to the analysis of quantum security, the present book employs an improved method for the evaluation of leaked information and identifies a remarkable relation between quantum security and quantum coherence. Taken together, these two improvements allow a better analysis of quantum state transmission. In addition, various types of the newly discovered uncertainty relation are explained. Presenting a wealth of new developments, the book introduces readers to the latest advances and challenges in quantum information. To aid in understanding, each chapter is accompanied by a set of exercises and solutions.

Until recently, measurable dynamics has been held as a highly theoretical mathematical topic with few generally known obvious links for practitioners in areas of applied mathematics. However, the advent of high-speed computers, rapidly developing algorithms, and new numerical methods has allowed for a tremendous

amount of progress and sophistication in efforts to represent the notion of a transfer operator discretely but to high resolution. This book connects many concepts in dynamical systems with mathematical tools from areas such as graph theory and ergodic theory. The authors introduce practical tools for applications related to measurable dynamical systems, coherent structures, and transport problems. The new and fast-developing computational tools discussed throughout the book allow for detailed analysis of real-world problems that are simply beyond the reach of traditional methods. Algebraic coding theory is a new and rapidly developing subject, popular for its many practical applications and for its fascinatingly rich mathematical structure. This book provides an elementary yet rigorous introduction to the theory of error-correcting codes. Based on courses given by the author over several years to advanced undergraduates and first-year graduated students, this guide includes a large number of exercises, all with solutions, making the book highly suitable for individual study. This book comprises selected papers of the International Conferences, CA and CES3 2011, held as Part of the Future Generation Information Technology Conference, FGIT 2011, in Conjunction with GDC 2011, Jeju Island, Korea, in December 2011. The papers presented were carefully reviewed and selected from numerous submissions and

focuse on the various aspects of control and automation, and circuits, control, communication, electricity, electronics, energy, system, signal and simulation.

Rapid advances in electronic and optical technology have enabled the implementation of powerful error-control codes, which are now used in almost the entire range of information systems with close to optimal performance. These codes and decoding methods are required for the detection and correction of the errors and erasures which inevitably occur in digital information during transmission, storage and processing because of noise, interference and other imperfections. Error-control coding is a complex, novel and unfamiliar area, not yet widely understood and appreciated. This book sets out to provide a clear description of the essentials of the subject, with comprehensive and up-to-date coverage of the most useful codes and their decoding algorithms. A practical engineering and information technology emphasis, as well as relevant background material and fundamental theoretical aspects, provides an in-depth guide to the essentials of Error-Control Coding. Provides extensive and detailed coverage of Block, Cyclic, BCH, Reed-Solomon, Convolutional, Turbo, and Low Density Parity Check (LDPC) codes, together with relevant aspects of Information Theory EXIT chart performance analysis for iteratively decoded error-

control techniques Heavily illustrated with tables,
diagrams, graphs, worked examples, and exercises
Invaluable companion website features slides of
figures, algorithm software, updates and solutions to
problems Offering a complete overview of Error
Control Coding, this book is an indispensable
resource for students, engineers and researchers in
the areas of telecommunications engineering,
communication networks, electronic engineering,
computer science, information systems and
technology, digital signal processing and applied
mathematics.

Applied Coding and Information Theory for
Engineers

A complete introduction to the basic and
intermediate concepts of image processing from the
leading people in the field Up-to-date content,
including statistical modeling of natural, anistropic
diffusion, image quality and the latest developments
in JPEG 2000 This comprehensive and state-of-the
art approach to image processing gives engineers
and students a thorough introduction, and includes
full coverage of key applications: image
watermarking, fingerprint recognition, face
recognition and iris recognition and medical imaging.
"This book combines basic image processing
techniques with some of the most advanced
procedures. Introductory chapters dedicated to
general principles are presented alongside detailed

application-orientated ones. As a result it is suitably adapted for different classes of readers, ranging from Master to PhD students and beyond." – Prof. Jean-Philippe Thiran, EPFL, Lausanne, Switzerland "Al Bovik's compendium proceeds systematically from fundamentals to today's research frontiers. Professor Bovik, himself a highly respected leader in the field, has invited an all-star team of contributors. Students, researchers, and practitioners of image processing alike should benefit from the Essential Guide." – Prof. Bernd Girod, Stanford University, USA "This book is informative, easy to read with plenty of examples, and allows great flexibility in tailoring a course on image processing or analysis." – Prof. Pamela Cosman, University of California, San Diego, USA A complete and modern introduction to the basic and intermediate concepts of image processing – edited and written by the leading people in the field An essential reference for all types of engineers working on image processing applications Up-to-date content, including statistical modelling of natural, anisotropic diffusion, image quality and the latest developments in JPEG 2000 This book is an evolution from my book A First Course in Information Theory published in 2002 when network coding was still at its infancy. The last few years have witnessed the rapid development of network coding into a research ?eld of its own in information science. With its root in infor- tion theory,

network coding has not only brought about a paradigm shift in network communications at large, but also had signi?cant in?uence on such speci?c research ?elds as coding theory, networking, switching, wireless c- munications,distributeddatasto rage,cryptography,andoptimizationtheory. While new applications of network coding keep emerging, the fundamental - sults that lay the foundation of the subject are more or less mature. One of the main goals of this book therefore is to present these results in a unifying and coherent manner. While the previous book focused only on information theory for discrete random variables, the current book contains two new chapters on information theory for continuous random variables, namely the chapter on di?erential entropy and the chapter on continuous-valued channels. With these topics included, the book becomes more comprehensive and is more suitable to be used as a textbook for a course in an electrical engineering department.

The protection of sensitive information against unauthorized access or fraudulent changes has been of prime concern throughout the centuries. Modern communication techniques, using computers connected through networks, make all data even more vulnerable for these threats. Also, new issues have come up that were not relevant before, e. g. how to add a (digital) signature to an electronic document in such a way that the signer can not deny

later on that the document was signed by him/her. Cryptology addresses the above issues. It is at the foundation of all information security. The techniques employed to this end have become increasingly mathematical of nature. This book serves as an introduction to modern cryptographic methods. After a brief survey of classical cryptosystems, it concentrates on three main areas. First of all, stream ciphers and block ciphers are discussed. These systems have extremely fast implementations, but sender and receiver have to share a secret key. Public key cryptosystems (the second main area) make it possible to protect data without a prearranged key. Their security is based on intractable mathematical problems, like the factorization of large numbers. The remaining chapters cover a variety of topics, such as zero-knowledge proofs, secret sharing schemes and authentication codes. Two appendices explain all mathematical prerequisites in great detail. One is on elementary number theory (Euclid's Algorithm, the Chinese Remainder Theorem, quadratic residues, inversion formulas, and continued fractions). The other appendix gives a thorough introduction to finite fields and their algebraic structure.

From the reviews: "This book nicely complements the existing literature on information and coding theory by concentrating on arbitrary nonstationary and/or nonergodic sources and channels with

arbitrarily large alphabets. Even with such generality the authors have managed to successfully reach a highly unconventional but very fertile exposition rendering new insights into many problems." -- MATHEMATICAL REVIEWS

This book provides a practical introduction to the theory and practice of coding and information theory for application in the field of electronic communications. It is written at an introductory level and assumes no prior background in coding or information theory. While the mathematical level is detailed, it is still introductory. Through a discussion that balances theory and practical applications and abandons the traditional "theorem-proof" format, this valuable book presents an overview of digital communication systems and the concept of information. It is written in a easy-to-follow conversational style that integrates practical engineering issues through formal and conceptual discussions of mathematical issues. It also makes extensive use of explicit examples that illustrate methods and theory throughout the book. For the professional, it provides an essential hands-on head start for real-world projects and situations. An essential reference for professional engineers in the field of electronic communications. Various measures of information are discussed in first chapter. Information rate, entropy and mark off models are presented. Second and third chapter deals with source coding. Shannon's encoding algorithm, discrete communication channels, mutual information, Shannon's first theorem are also presented. Huffman coding and Shannon-Fano coding is also discussed. Continuous

channels are discussed in fourth chapter. Channel
coding theorem and channel capacity theorems are also
presented. Block codes are discussed in chapter fifth,
sixth and seventh. Linear block codes, Hamming codes,
syndrome decoding is presented in detail. Structure and
properties of cyclic codes, encoding and syndrome
decoding for cyclic codes is also discussed. Additional
cyclic codes such as RS codes, Golay codes, burst error
correction is also discussed. Last chapter presents
convolutional codes. Time domain, transform domain
approach, code tree, code trellis, state diagram, Viterbi
decoding is discussed in detail.
Error correcting coding is often analyzed in terms of its
application to the separate levels within the data network
in isolation from each other. In this fresh approach, the
authors consider the data network as a superchannel (a
multi-layered entity) which allows error correcting coding
to be evaluated as it is applied to a number of network
layers as a whole. By exposing the problems of applying
error correcting coding in data networks, and by
discussing coding theory and its applications, this
original technique shows how to correct errors in the
network through joint coding at different network layers.
Discusses the problem of reconciling coding applied to
different layers using a superchannel approach Includes
thorough coverage of all the key codes: linear block
codes, Hamming, BCH and Reed-Solomon codes, LDPC
codes decoding, as well as convolutional, turbo and
iterative coding Considers new areas of application of
error correcting codes such as transport coding, code-
based cryptosystems and coding for image compression

Demonstrates how to use error correcting coding to control such important data characteristics as mean message delay Provides theoretical explanations backed up by numerous real-world examples and practical recommendations Features a companion website containing additional research results including new constructions of LDPC codes, joint error-control coding and synchronization, Reed-Muller codes and their list decoding By progressing from theory through to practical problem solving, this resource contains invaluable advice for researchers, postgraduate students, engineers and computer scientists interested in data communications and applications of coding theory.

This volume contains the Proceedings of an International Conference on Noncommutative Rings and Their Applications, held July 1-4, 2013, at the Universite d'Artois, Lens, France. It presents recent developments in the theories of noncommutative rings and modules over such rings as well as applications of these to coding theory, enveloping algebras, and Leavitt path algebras. Material from the course ``Foundations of Algebraic Coding Theory``, given by Steven Dougherty, is included and provides the reader with the history and background of coding theory as well as the interplay between coding theory and algebra. In module theory, many new results related to (almost) injective modules, injective hulls and automorphism-invariant modules are presented. Broad generalizations of classical projective covers are studied and category theory is used to describe the structure of some modules. In some papers related to more classical ring theory such as quasi duo rings or clean elements,

new points of view on classical conjectures and standard open problems are given. Descriptions of codes over local commutative Frobenius rings are discussed, and a list of open problems in coding theory is presented within their context.

Coding theory draws on a remarkable selection of mathematical topics, both pure and applied. The various contributions in this volume introduce coding theory and its most recent developments and applications, emphasizing both mathematical and engineering perspectives on the subject. This volume covers four important areas in coding theory: algebraic geometry codes, graph-based codes, space-time codes, and quantum codes. Both students and seasoned researchers will benefit from the extensive and self-contained discussions of the development and recent progress in these areas. Information for our distributors: Titles in this series are co-published with International Press, Cambridge, MA.

This book provides an up-to-date introduction to information theory. It provides the first comprehensive treatment of the theory of I-Measure, network coding theory, Shannon and non-Shannon type information inequalities, and a relation between entropy and group theory.

DIVAnalysis of channel models and proof of coding theorems; study of specific coding systems; and study of statistical properties of information sources. Sixty problems, with solutions. Advanced undergraduate to graduate level. /div

Csiszár and Körner's book is widely regarded as a

classic in the field of information theory, providing deep insights and expert treatment of the key theoretical issues. It includes in-depth coverage of the mathematics of reliable information transmission, both in two-terminal and multi-terminal network scenarios. Updated and considerably expanded, this new edition presents unique discussions of information theoretic secrecy and of zero-error information theory, including the deep connections of the latter with extremal combinatorics. The presentations of all core subjects are self contained, even the advanced topics, which helps readers to understand the important connections between seemingly different problems. Finally, 320 end-of-chapter problems, together with helpful hints for solving them, allow readers to develop a full command of the mathematical techniques. It is an ideal resource for graduate students and researchers in electrical and electronic engineering, computer science and applied mathematics.
Collected here are papers that were presented at or inspired by the DIMACS workshop, Algebraic Coding Theory and Information Theory (Rutgers University, Piscataway, NJ). Among the topics discussed are universal data compression, graph theoretical ideas in the construction of codes and lattices, decoding algorithms, and computation of capacity in various communications schemes. The book is suitable for graduate students and researchers interested in coding and information theory.
This book traces the history of the MIT Department

of Mathematics-one of the most important mathematics departments in the world-through candid, in-depth, lively conversations with a select and diverse group of its senior members. The process reveals much about the motivation, path, and impact of research mathematicians in a society that owes so mu
Books on information theory and coding have proliferated over the last few years, but few succeed in covering the fundamentals without losing students in mathematical abstraction. Even fewer build the essential theoretical framework when presenting algorithms and implementation details of modern coding systems. Without abandoning the theoret
55% new material in the latest edition of this "must-have for students and practitioners of image & video processing! This Handbook is intended to serve as the basic reference point on image and video processing, in the field, in the research laboratory, and in the classroom. Each chapter has been written by carefully selected, distinguished experts specializing in that topic and carefully reviewed by the Editor, Al Bovik, ensuring that the greatest depth of understanding be communicated to the reader. Coverage includes introductory, intermediate and advanced topics and as such, this book serves equally well as classroom textbook as reference resource. • Provides practicing engineers and students with a highly accessible resource for

learning and using image/video processing theory and algorithms • Includes a new chapter on image processing education, which should prove invaluable for those developing or modifying their curricula • Covers the various image and video processing standards that exist and are emerging, driving today's explosive industry • Offers an understanding of what images are, how they are modeled, and gives an introduction to how they are perceived • Introduces the necessary, practical background to allow engineering students to acquire and process their own digital image or video data • Culminates with a diverse set of applications chapters, covered in sufficient depth to serve as extensible models to the reader's own potential applications About the Editor... Al Bovik is the Cullen Trust for Higher Education Endowed Professor at The University of Texas at Austin, where he is the Director of the Laboratory for Image and Video Engineering (LIVE). He has published over 400 technical articles in the general area of image and video processing and holds two U.S. patents. Dr. Bovik was Distinguished Lecturer of the IEEE Signal Processing Society (2000), received the IEEE Signal Processing Society Meritorious Service Award (1998), the IEEE Third Millennium Medal (2000), and twice was a two-time Honorable Mention winner of the international Pattern Recognition Society Award. He is a Fellow of the IEEE, was Editor-in-Chief, of the IEEE

Transactions on Image Processing (1996-2002), has served on and continues to serve on many other professional boards and panels, and was the Founding General Chairman of the IEEE International Conference on Image Processing which was held in Austin, Texas in 1994. * No other resource for image and video processing contains the same breadth of up-to-date coverage * Each chapter written by one or several of the top experts working in that area * Includes all essential mathematics, techniques, and algorithms for every type of image and video processing used by electrical engineers, computer scientists, internet developers, bioengineers, and scientists in various, image-intensive disciplines

Covering both the theoretical and practical aspects of fault-tolerant mobile systems, and fault tolerance and analysis, this book tackles the current issues of reliability-based optimization of computer networks, fault-tolerant mobile systems, and fault tolerance and reliability of high speed and hierarchical networks. The book is divided into six parts to facilitate coverage of the material by course instructors and computer systems professionals. The sequence of chapters in each part ensures the gradual coverage of issues from the basics to the most recent developments. A useful set of references, including electronic sources, is listed at the end of each chapter. Contents:Fundamental Concepts in Fault

Tolerance and Reliability AnalysisFault Modeling, Simulation and DiagnosisError Control and Self-Checking CircuitsFault Tolerance in Multiprocessor SystemsFault-Tolerant Routing in Multi-Computer NetworksFault Tolerance and Reliability in Hierarchical Interconnection NetworksFault Tolerance and Reliability of Computer NetworksFault Tolerance in High Speed Switching NetworksFault Tolerance in Distributed and Mobile Computing SystemsFault Tolerance in Mobile NetworksReliability and Yield Enhancement of VLSI/WSI CircuitsDesign of fault-tolerant Processor ArraysAlgorithm-Based Fault ToleranceSystem Level Diagnosis ISystem Level Diagnosis IIFault Tolerance and Reliability of RAID SystemsHigh Availability in Computer Systems Readership: Computer engineers, computer scientists, information scientists, graduate and senior undergraduate students in information science and computer engineering. Keywords:Fault Tolerance;Reliability;Availability;Fault Modeling;Fault Diagnosis;Network ReliabilityKey Features:Comprehensive coverage of issues in fault tolerance and reliability analysisSimple treatment of difficult issues via examples with figures, tables and graphs

Csiszár and Körner's book is widely regarded as a classic in the field of information theory, providing deep insights and expert treatment of the key

theoretical issues. It includes in-depth coverage of the mathematics of reliable information transmission, both in two-terminal and multi-terminal network scenarios. Updated and considerably expanded, this new edition presents unique discussions of information theoretic secrecy and of zero-error information theory, including the deep connections of the latter with extremal combinatorics. The presentations of all core subjects are self contained, even the advanced topics, which helps readers to understand the important connections between seemingly different problems. Finally, 320 end-of-chapter problems, together with helpful solving hints, allow readers to develop a full command of the mathematical techniques. It is an ideal resource for graduate students and researchers in electrical and electronic engineering, computer science and applied mathematics.

Ergodic theory is hard to study because it is based on measure theory, which is a technically difficult subject to master for ordinary students, especially for physics majors. Many of the examples are introduced from a different perspective than in other books and theoretical ideas can be gradually absorbed while doing computer experiments. Theoretically less prepared students can appreciate the deep theorems by doing various simulations. The computer experiments are simple but they have close ties with theoretical implications. Even the

researchers in the field can benefit by checking their conjectures, which might have been regarded as unrealistic to be programmed easily, against numerical output using some of the ideas in the book. One last remark: The last chapter explains the relation between entropy and data compression, which belongs to information theory and not to ergodic theory. It will help students to gain an understanding of the digital technology that has shaped the modern information society.

A valuable teaching aid. Provides relevant background material, many examples and clear solutions to problems taken from real exam papers. Since the main principles of applied information theory were formulated in the 1940s, the science has been greatly developed and today its areas of application range from traditional communication engineering problems to humanities and the arts. Interdisciplinary in scope, this book is a single-source reference for all applications areas, including engineering, radar, computing technology, television, the life sciences (including biology, physiology and psychology) and arts criticism. A review of the current state of information theory is provided; the author also presents several generalized and original results, and gives a treatment of various problems. This is a reference for both specialists and non-professionals in information theory and general cybernetics.

This book is intended to introduce coding theory and information theory to undergraduate students of

mathematics and computer science. It begins with a review of probablity theory as applied to finite sample spaces and a general introduction to the nature and types of codes. The two subsequent chapters discuss information theory: efficiency of codes, the entropy of information sources, and Shannon's Noiseless Coding Theorem. The remaining three chapters deal with coding theory: communication channels, decoding in the presence of errors, the general theory of linear codes, and such specific codes as Hamming codes, the simplex codes, and many others.

This book is based on lectures given by the author at the IBM European Systems Research Institute (ESRI) in Geneva. Information Theory on the syntactic level, as introduced by Claude Shannon in 1949, has many limitations when applied to information processing by computers. But in spite of some obvious shortcomings, the underlying principles are of fundamental importance for systems engineers in understanding the nature of the problems of handling information, its acquisition, storage, processing, and interpretation. The lectures, as presented in this book, attempt to give an exposition of the lovical foundation and basic principles, and to provide at the same time a basis for further study in more specific areas of this expaning theory, such as coding, detection, pattern recognition, and filtering. Most of the problems in Appendix C are intended as extensions of the text, while calling for actjve participation by the student. Some other problems are direct applications of the theory to specific situations. Some problems require extensive numerical calculations. It is assumed in those

cases that the student has access to a computer and that he is capable of writing the necessary programs. The student is assumed to have a good command of the calculus, and of the theory of probability as well as statistics. Therefore no basic mathematical concepts are discussed in this IV book. The Fourier transform and some related mathematical concepts are introduced in Appendix A -- Preface.

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A concise, easy-to-read guide, introducing beginners to the engineering background of modern communication systems, from mobile phones to data storage. Assuming only basic knowledge of high-school mathematics and including many practical examples and exercises to aid understanding, this is ideal for anyone who needs a quick introduction to the subject.

Information Theory and Statistics: A Tutorial is concerned with applications of information theory concepts in statistics, in the finite alphabet setting. The topics covered include large deviations, hypothesis testing, maximum likelihood estimation in exponential families, analysis of contingency tables, and iterative algorithms with an "information geometry" background. Also, an introduction is provided to the theory of universal coding, and to statistical inference via the minimum description length principle motivated by that theory. The tutorial does not assume the reader has an in-depth knowledge of Information Theory or statistics. As such, Information Theory and Statistics: A Tutorial, is an excellent introductory text to this highly-important

topic in mathematics, computer science and electrical engineering. It provides both students and researchers with an invaluable resource to quickly get up to speed in the field.

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