

Introduction To Complexity Theory Computational Logic

An advanced textbook giving a broad, modern view of the computational complexity theory of boolean circuits, with extensive references, for theoretical computer scientists and mathematicians.

The two main themes of this book, logic and complexity, are both essential for understanding the main problems about the foundations of mathematics. Logical Foundations of Mathematics and Computational Complexity covers a broad spectrum of results in logic and set theory that are relevant to the foundations, as well as the results in computational complexity and the interdisciplinary area of proof complexity. The author presents his ideas on how these areas are connected, what are the most fundamental problems and how they should be approached. In particular, he argues that complexity is as important for foundations as are the more traditional concepts of computability and provability. Emphasis is on explaining the essence of concepts and the ideas of proofs, rather than presenting precise formal statements and full proofs. Each section starts with concepts and results easily explained, and gradually proceeds to more difficult ones. The notes after each section present some formal definitions, theorems and proofs. Logical Foundations of Mathematics and Computational Complexity is aimed at graduate students of all fields of mathematics who are interested in logic, complexity and foundations. It will also be of interest for both physicists and philosophers who are curious to learn the basics of logic and complexity theory.

Computational complexity theory is the study of the quantitative laws that govern computing. During the last 25 years, this field has grown into a rich mathematical theory. Currently one of the most active research areas in computer science, complexity theory is of considerable interest to mathematicians as well, since some of the key open problems in this field raise basic questions about the nature of mathematics. Many experts in complexity theory believe that, in coming decades, the strongest influence on the development of mathematics will come from the extended use of computing and from concepts and problems arising in computer science. This volume contains the proceedings of the AMS Short Course on Computational Complexity Theory, held at the Joint Mathematics Meetings in Atlanta in January 1988. The purpose of the short course was to provide an overview of complexity theory and to describe some of the current developments in the field. The papers presented here represent contributions by some of the top experts in this burgeoning area of research.

Constraint Handling Rules (CHR) is both a theoretical formalism and a practical programming language. This book provides an overview of CHR research based on a reviewed selection of doctoral theses. After a basic introduction to CHR, the book presents results from three different areas of CHR research: compilation and optimization, execution strategies, and program analysis. The chapters offer in-depth treatises of selected subjects, supported by a wealth of examples. The book is ideal for master students, lecturers, and researchers.

The book is an overview of theoretical and applied informatics. It introduces the reader to the history of information technologies and computer science.

Preliminaries. Finite automata and regular expressions. Properties of regular sets. Context-free grammars. Pushdown automata; Properties of context-free languages. Turing machines. Undecidability. The Chomsky hierarchy. Deterministic context-free languages. Closure properties of families of languages. Computational complexity theory. Intractable problems. Highlights of other important language classes.

This classic book on formal languages, automata theory, and computational complexity has been updated to present theoretical concepts in a concise and straightforward manner with the increase of hands-on, practical applications. This new edition comes with Gradiance, an online assessment tool developed for computer science. Gradiance is the most advanced online assessment tool developed for the computer science discipline. With its innovative underlying technology, Gradiance turns basic homework assignments and programming labs into an interactive learning experience for students. By using a series of root questions and hints, it not only tests a student's capability, but actually simulates a one-on-one teacher-student tutorial that allows for the student to more easily learn the material. Through the programming labs, instructors are capable of testing, tracking, and honing their students' skills, both in terms of syntax and semantics, with an unprecedented level of assessment never before offered. For more information about Gradiance, please visit www.aw.com/gradiance.

The aim of this textbook is to present an account of the theory of computation. After introducing the concept of a model of computation and presenting various examples, the author explores the limitations of effective computation via basic recursion theory. Self-reference and other methods are introduced as fundamental and basic tools for constructing and manipulating algorithms. From there the book considers the complexity of computations and the notion of a complexity measure is introduced. Finally, the book culminates in considering time and space measures and in classifying computable functions as being either feasible or not. The author assumes only a basic familiarity with discrete mathematics and computing, making this textbook ideal for a graduate-level introductory course. It is based on many such courses presented by the author and so numerous exercises are included. In addition, the solutions to most of these exercises are provided.

This textbook connects three vibrant areas at the interface between economics and computer science: algorithmic game theory, computational social choice, and fair division. It thus offers an interdisciplinary treatment of collective decision making from an economic and computational perspective. Part I introduces to algorithmic game theory, focusing on both noncooperative and cooperative game theory. Part II introduces to computational social choice, focusing on both preference aggregation (voting) and judgment aggregation. Part III introduces to fair division, focusing on the division of both a single divisible resource ("cake-cutting") and multiple indivisible and unshareable resources ("multiagent resource allocation"). In all these parts, much weight is given to the algorithmic and complexity-theoretic aspects of problems arising in these areas, and the interconnections between the three parts are of central interest.

Quantum information theory has revolutionised our view on the true nature of information and has led to such intriguing topics as teleportation and quantum computation. The field - by its very nature strongly interdisciplinary, with deep roots in the foundations both of quantum mechanics and of information theory and computer science - has become a major subject for scientists working in fields as diverse as quantum optics, superconductivity or information theory, all the way to computer engineers.

This book is a collection of advanced research/survey papers by eminent research workers in the Recursion theory.

This volume is composed of six contributions derived from the lectures given during the UIMP-RSME Lluís Santaló Summer School on "Recent Advances in Real Complexity and Computation", held July 16-20, 2012, in Santander, Spain. The goal of this Summer School was to present some of the recent advances on Smale's 17th Problem: "Can a zero of n complex polynomial equations in n unknowns be found approximately, on the average, in polynomial time with a uniform algorithm?" These papers cover several aspects of this problem: from numerical to symbolic methods in polynomial equation solving, computational complexity aspects (both worst and average cases and both upper and lower complexity bounds) as well as aspects of the underlying geometry of the problem. Some of the contributions also deal with either real or multiple solutions solving.

Now you can clearly present even the most complex computational theory topics to your students with Sipser's distinct, market-leading INTRODUCTION TO THE THEORY OF COMPUTATION, 3E. The number one choice for today's computational theory course, this highly anticipated revision retains the unmatched clarity and thorough coverage that make it a leading text for upper-level undergraduate and introductory graduate students. This edition continues author Michael Sipser's well-known, approachable style with timely revisions, additional exercises, and more memorable examples in key areas. A new first-of-its-kind theoretical treatment of deterministic context-free languages is ideal for a better understanding of parsing and LR(k) grammars. This edition's refined presentation ensures a trusted accuracy and clarity that make the challenging study of computational theory accessible and intuitive to students while maintaining the subject's rigor and formalism. Readers gain a solid understanding of the fundamental mathematical properties of computer hardware, software, and applications with a blend of practical and philosophical coverage and mathematical treatments, including advanced theorems and proofs. INTRODUCTION TO THE THEORY OF COMPUTATION, 3E's comprehensive coverage makes this an ideal ongoing reference tool for those studying theoretical computing. Important Notice: Media content referenced within the product description or the product text may not be available in the ebook version.

An introduction to computational complexity theory, its connections and interactions with mathematics, and its central role in the natural and social sciences, technology, and philosophy Mathematics and Computation provides a broad, conceptual overview of computational complexity theory—the mathematical study of efficient computation. With important practical applications to computer science and industry, computational complexity theory has evolved into a highly interdisciplinary field, with strong links to most mathematical areas and to a growing number of scientific endeavors. Avi Wigderson takes a sweeping survey of complexity theory, emphasizing the field's insights and challenges. He explains the ideas and motivations leading to key models, notions, and results. In particular, he looks at algorithms and complexity, computations and proofs, randomness and interaction, quantum and arithmetic computation, and cryptography and learning, all as parts of a cohesive whole with numerous cross-influences. Wigderson illustrates the immense breadth of the field, its beauty and richness, and its diverse and growing interactions with other areas of mathematics. He ends with a comprehensive look at the theory of computation, its methodology and aspirations, and the unique and fundamental ways in which it has shaped and will further shape science, technology, and society. For further reading, an extensive bibliography is provided for all topics covered. Mathematics and Computation is useful for undergraduate and graduate students in mathematics, computer science, and related fields, as well as researchers and teachers in these fields. Many parts require little background, and serve as an invitation to newcomers seeking an introduction to the theory of computation. Comprehensive coverage of computational complexity theory, and beyond High-level, intuitive exposition, which brings conceptual clarity to this central and dynamic scientific discipline Historical accounts of the evolution and motivations of central concepts and models A broad view of the theory of computation's influence on science, technology, and society Extensive bibliography

Limits of Computation: An Introduction to the Undecidable and the Intractable offers a gentle introduction to the theory of computational complexity. It explains the difficulties of computation, addressing problems that have no algorithm at all and problems that cannot be solved efficiently. The book enables readers to understand: What does it mean for a problem to be unsolvable or to be NP-complete? What is meant by a computation and what is a general model of a computer? What does it mean for an algorithm to exist and what kinds of problems have no algorithm? What problems have algorithms but the algorithm may take centuries to finish? Developed from the authors' course on computational complexity theory, the text is suitable for advanced undergraduate and beginning graduate students without a strong background in theoretical computer science. Each chapter presents the fundamentals, examples, complete proofs of theorems, and a wide range of exercises.

This revised and extensively expanded edition of Computability and Complexity Theory comprises essential materials that are core knowledge in the theory of computation. The book is self-contained, with a preliminary chapter describing key mathematical concepts and notations. Subsequent chapters move from the qualitative aspects of classical computability theory to the quantitative aspects of complexity theory. Dedicated chapters on undecidability, NP-completeness, and relative computability focus on the limitations of computability and the distinctions between feasible and intractable. Substantial new content in this edition includes: a chapter on nonuniformity studying Boolean circuits, advice classes and the important result of Karp-Lipton. a chapter studying properties of the fundamental probabilistic complexity classes a study of the alternating Turing machine and uniform circuit classes. an introduction of counting classes, proving the famous results of Valiant and Vazirani and of Toda a thorough treatment of the proof that IP is identical to PSPACE With its accessibility and well-devised organization, this text/reference is an excellent resource and guide for those looking to develop a solid grounding in the theory of computing. Beginning graduates, advanced undergraduates, and professionals involved in theoretical computer science, complexity theory, and computability will find the book an essential and practical learning tool. Topics and features: Concise, focused materials cover the most

fundamental concepts and results in the field of modern complexity theory, including the theory of NP-completeness, NP-hardness, the polynomial hierarchy, and complete problems for other complexity classes Contains information that otherwise exists only in research literature and presents it in a unified, simplified manner Provides key mathematical background information, including sections on logic and number theory and algebra Supported by numerous exercises and supplementary problems for reinforcement and self-study purposes

The classical theory of computation has its origins in the work of Goedel, Turing, Church, and Kleene and has been an extraordinarily successful framework for theoretical computer science. The thesis of this book, however, is that it provides an inadequate foundation for modern scientific computation where most of the algorithms are real number algorithms. The goal of this book is to develop a formal theory of computation which integrates major themes of the classical theory and which is more directly applicable to problems in mathematics, numerical analysis, and scientific computing. Along the way, the authors consider such fundamental problems as: * Is the Mandelbrot set decidable? * For simple quadratic maps, is the Julia set a halting set? * What is the real complexity of Newton's method? * Is there an algorithm for deciding the knapsack problem in a polynomial number of steps? * Is the Hilbert Nullstellensatz intractable? * Is the problem of locating a real zero of a degree four polynomial intractable? * Is linear programming tractable over the reals? The book is divided into three parts: The first part provides an extensive introduction and then proves the fundamental NP-completeness theorems of Cook-Karp and their extensions to more general number fields as the real and complex numbers. The later parts of the book develop a formal theory of computation which integrates major themes of the classical theory and which is more directly applicable to problems in mathematics, numerical analysis, and scientific computing.

This book comprises revised full versions of lectures given during the 9th European Summer School in Logic, Languages, and Information, ESSLLI'97, held in Aix-en-Provence, France, in August 1997. The six lectures presented introduce the reader to the state of the art in the area of generalized quantifiers and computation. Besides an introductory survey by the volume editor various aspects of generalized quantifiers are studied in depth.

An accessible and rigorous textbook for introducing undergraduates to computer science theory What Can Be Computed? is a uniquely accessible yet rigorous introduction to the most profound ideas at the heart of computer science. Crafted specifically for undergraduates who are studying the subject for the first time, and requiring minimal prerequisites, the book focuses on the essential fundamentals of computer science theory and features a practical approach that uses real computer programs (Python and Java) and encourages active experimentation. It is also ideal for self-study and reference. The book covers the standard topics in the theory of computation, including Turing machines and finite automata, universal computation, nondeterminism, Turing and Karp reductions, undecidability, time-complexity classes such as P and NP, and NP-completeness, including the Cook-Levin Theorem. But the book also provides a broader view of computer science and its historical development, with discussions of Turing's original 1936 computing machines, the connections between undecidability and Gödel's incompleteness theorem, and Karp's famous set of twenty-one NP-complete problems. Throughout, the book recasts traditional computer science concepts by considering how computer programs are used to solve real problems. Standard theorems are stated and proven with full mathematical rigor, but motivation and understanding are enhanced by considering concrete implementations. The book's examples and other content allow readers to view demonstrations of—and to experiment with—a wide selection of the topics it covers. The result is an ideal text for an introduction to the theory of computation. An accessible and rigorous introduction to the essential fundamentals of computer science theory, written specifically for undergraduates taking introduction to the theory of computation Features a practical, interactive approach using real computer programs (Python in the text, with forthcoming Java alternatives online) to enhance motivation and understanding Gives equal emphasis to computability and complexity Includes special topics that demonstrate the profound nature of key ideas in the theory of computation Lecture slides and Python programs are available at whatcanbecomputed.com

This comprehensive introduction to algebraic complexity theory presents new techniques for analyzing P vs NP and matrix multiplication. Complexity theory is a central field of the theoretical foundations of computer science, concerned with the general study of the intrinsic complexity of computational tasks. This book offers a conceptual perspective on complexity theory intended to serve as an introduction for advanced undergraduates and graduates.

The Theory of Computation or Automata and Formal Languages assumes significance as it has a wide range of applications in compiler design, robotics, Artificial Intelligence (AI), and knowledge engineering. This compact and well-organized book provides a clear analysis of the subject with its emphasis on concepts which are reinforced with a large number of worked-out examples. The book begins with an overview of mathematical preliminaries. The initial chapters discuss in detail about the basic concepts of formal languages and automata, the finite automata, regular languages and regular expressions, and properties of regular languages. The text then goes on to give a detailed description of context-free languages, pushdown automata and computability of Turing machine, with its complexity and recursive features. The book concludes by giving clear insights into the theory of computability and computational complexity. This text is primarily designed for undergraduate (BE/B.Tech.) students of Computer Science and Engineering (CSE) and Information Technology (IT), postgraduate students (M.Sc.) of Computer Science, and Master of Computer Applications (MCA). Salient Features • One complete chapter devoted to a discussion on undecidable problems. • Numerous worked-out examples given to illustrate the concepts. • Exercises at the end of each chapter to drill the students in self-study. • Sufficient theories with proofs.

Computational Complexity Theory is the study of how much of a given resource is required to perform the computations that interest us the most. Four decades of fruitful research have produced a rich and subtle theory of the relationship between different resource measures and problems. At the core of the theory are some of the most alluring open problems in mathematics. This book presents three weeks of lectures from the IAS/Park City Mathematics Institute Summer School on computational complexity. The first week gives a general introduction to the field, including descriptions of the basic mo.

Taking a practical approach, this modern introduction to the theory of computation focuses on the study of problem solving through computation in the presence of realistic resource constraints. The Theory of Computation explores questions and methods that characterize theoretical computer science while relating all developments to practical issues in computing. The book establishes clear limits to computation, relates these limits to resource usage, and explores possible avenues of compromise through approximation and randomization. The book also provides an overview of current areas of research in theoretical computer science that are likely to have a significant impact on the practice of computing within the next few years.

With this book, the authors are trying to present in a unified treatment an introduction to the central ideas and their applications of the Kolmogorov Complexity, the theory dealing with the quantity of information in individual objects. This book is appropriate for either a one- or two-semester introductory course in departments of computer science, mathematics, physics, probability theory and statistics, artificial intelligence, and philosophy. Although the mathematical theory of Kolmogorov complexity contains sophisticated mathematics, the amount of math one needs to know to apply the notions in widely divergent areas, is very little. The authors' purpose is to develop the theory in detail and outline a wide range of illustrative applications. This book is an attempt to grasp the mass of fragmented knowledge of this fascinating theory. Chapter 1 is a compilation of material on the diverse notations and disciplines we draw upon in order to make the book self-contained. The mathematical theory of Kolmogorov complexity is

treated in chapters 2-4; the applications are treated in chapters 4-8.

What is "topological" about topological quantum states? How many types of topological quantum phases are there? What is a zero-energy Majorana mode, how can it be realized in a solid state system, and how can it be used as a platform for topological quantum computation? What is quantum computation and what makes it different from classical computation? Addressing these and other related questions, *Introduction to Topological Quantum Matter & Quantum Computation* provides an introduction to and a synthesis of a fascinating and rapidly expanding research field emerging at the crossroads of condensed matter physics, mathematics, and computer science. Providing the big picture, this book is ideal for graduate students and researchers entering this field as it allows for the fruitful transfer of paradigms and ideas amongst different areas, and includes many specific examples to help the reader understand abstract and sometimes challenging concepts. It explores the topological quantum world beyond the well-known topological insulators and superconductors and emphasizes the deep connections with quantum computation. It addresses key principles behind the classification of topological quantum phases and relevant mathematical concepts and discusses models of interacting and noninteracting topological systems, such as the toric code and the p-wave superconductor. The book also covers the basic properties of anyons, and aspects concerning the realization of topological states in solid state structures and cold atom systems. Quantum computation is also presented using a broad perspective, which includes fundamental aspects of quantum mechanics, such as Bell's theorem, basic concepts in the theory of computation, such as computational models and computational complexity, examples of quantum algorithms, and elements of classical and quantum information theory.

This textbook is uniquely written with dual purpose. It covers core material in the foundations of computing for graduate students in computer science and also provides an introduction to some more advanced topics for those intending further study in the area. This innovative text focuses primarily on computational complexity theory: the classification of computational problems in terms of their inherent complexity. The book contains an invaluable collection of lectures for first-year graduates on the theory of computation. Topics and features include more than 40 lectures for first year graduate students, and a dozen homework sets and exercises.

The first unified introduction and reference for the field of computational complexity. Virtually non-existent only 25 years ago, computational complexity has expanded tremendously and now comprises a major part of the research activity in theoretical science.

Using a balanced approach that is partly algorithmic and partly structuralist, this book systematically reviews the most significant results obtained in the study of computational complexity theory. **KEY TOPICS:** Considers properties of complexity classes, inclusions between classes, implications between several hypotheses about complexity classes, and identification of structural properties of sets that affect their computational complexity. Features over 120 worked examples, over 200 problems, and 400 figures. For those interested in complexity and computability, algorithm design, operations research, and combinatorial mathematics.

Introduction to Languages and the Theory of Computation is an introduction to the theory of computation that emphasizes formal languages, automata and abstract models of computation, and computability; it also includes an introduction to computational complexity and NP-completeness. Through the study of these topics, students encounter profound computational questions and are introduced to topics that will have an ongoing impact in computer science. Once students have seen some of the many diverse technologies contributing to computer science, they can also begin to appreciate the field as a coherent discipline. A distinctive feature of this text is its gentle and gradual introduction of the necessary mathematical tools in the context in which they are used. Martin takes advantage of the clarity and precision of mathematical language but also provides discussion and examples that make the language intelligible to those just learning to read and speak it. The material is designed to be accessible to students who do not have a strong background in discrete mathematics, but it is also appropriate for students who have had some exposure to discrete math but whose skills in this area need to be consolidated and sharpened.

"The book is outstanding and admirable in many respects. ... is necessary reading for all kinds of readers from undergraduate students to top authorities in the field." *Journal of Symbolic Logic* Written by two experts in the field, this is the only comprehensive and unified treatment of the central ideas and applications of Kolmogorov complexity. The book presents a thorough treatment of the subject with a wide range of illustrative applications. Such applications include the randomness of finite objects or infinite sequences, Martin-Löf tests for randomness, information theory, computational learning theory, the complexity of algorithms, and the thermodynamics of computing. It will be ideal for advanced undergraduate students, graduate students, and researchers in computer science, mathematics, cognitive sciences, philosophy, artificial intelligence, statistics, and physics. The book is self-contained in that it contains the basic requirements from mathematics and computer science. Included are also numerous problem sets, comments, source references, and hints to solutions of problems. New topics in this edition include Omega numbers, Kolmogorov–Loveland randomness, universal learning, communication complexity, Kolmogorov's random graphs, time-limited universal distribution, Shannon information and others.

Algorithms and Theory of Computation Handbook, Second Edition: General Concepts and Techniques provides an up-to-date compendium of fundamental computer science topics and techniques. It also illustrates how the topics and techniques come together to deliver efficient solutions to important practical problems. Along with updating and revising many of the existing chapters, this second edition contains four new chapters that cover external memory and parameterized algorithms as well as computational number theory and algorithmic coding theory. This best-selling handbook continues to help computer professionals and engineers find significant information on various algorithmic topics. The expert contributors clearly define the terminology, present basic results and techniques, and offer a number of current references to the in-depth literature. They also provide a glimpse of the major research issues concerning the relevant topics.

This textbook provides a comprehensive and reader-friendly introduction to the field of computational social science (CSS). Presenting a unified treatment, the text examines in detail the four key methodological approaches of automated social information extraction, social network analysis, social complexity theory, and social simulation modeling. This updated new edition has been enhanced with numerous review questions and exercises to test what has been learned, deepen understanding through problem-solving, and to practice writing code to implement ideas. **Topics and features:** contains more than a thousand questions and exercises, together with a list of acronyms and a glossary; examines the similarities and differences between computers and social systems; presents a focus on automated information extraction; discusses the measurement, scientific laws, and generative theories of social complexity in CSS; reviews the methodology of

social simulations, covering both variable- and object-oriented models.

Computability and complexity theory should be of central concern to practitioners as well as theorists. Unfortunately, however, the field is known for its impenetrability. Neil Jones's goal as an educator and author is to build a bridge between computability and complexity theory and other areas of computer science, especially programming. In a shift away from the Turing machine- and Gdel number-oriented classical approaches, Jones uses concepts familiar from programming languages to make computability and complexity more accessible to computer scientists and more applicable to practical programming problems. According to Jones, the fields of computability and complexity theory, as well as programming languages and semantics, have a great deal to offer each other. Computability and complexity theory have a breadth, depth, and generality not often seen in programming languages. The programming language community, meanwhile, has a firm grasp of algorithm design, presentation, and implementation. In addition, programming languages sometimes provide computational models that are more realistic in certain crucial aspects than traditional models. New results in the book include a proof that constant time factors do matter for its programming-oriented model of computation. (In contrast, Turing machines have a counterintuitive "constant speedup" property: that almost any program can be made to run faster, by any amount. Its proof involves techniques irrelevant to practice.) Further results include simple characterizations in programming terms of the central complexity classes PTIME and LOGSPACE, and a new approach to complete problems for NLOGSPACE, PTIME, NPTIME, and PSPACE, uniformly based on Boolean programs. Foundations of Computing series

The algorithmic solution of problems has always been one of the major concerns of mathematics. For a long time such solutions were based on an intuitive notion of algorithm. It is only in this century that metamathematical problems have led to the intensive search for a precise and sufficiently general formalization of the notions of computability and algorithm. In the 1930s, a number of quite different concepts for this purpose were proposed, such as Turing machines, WHILE-programs, recursive functions, Markov algorithms, and Thue systems. All these concepts turned out to be equivalent, a fact summarized in Church's thesis, which says that the resulting definitions form an adequate formalization of the intuitive notion of computability. This had and continues to have an enormous effect. First of all, with these notions it has been possible to prove that various problems are algorithmically unsolvable. Among of group these undecidable problems are the halting problem, the word problem theory, the Post correspondence problem, and Hilbert's tenth problem. Secondly, concepts like Turing machines and WHILE-programs had a strong influence on the development of the first computers and programming languages. In the era of digital computers, the question of finding efficient solutions to algorithmically solvable problems has become increasingly important. In addition, the fact that some problems can be solved very efficiently, while others seem to defy all attempts to find an efficient solution, has called for a deeper understanding of the intrinsic computational difficulty of problems.

This beginning graduate textbook describes both recent achievements and classical results of computational complexity theory. Requiring essentially no background apart from mathematical maturity, the book can be used as a reference for self-study for anyone interested in complexity, including physicists, mathematicians, and other scientists, as well as a textbook for a variety of courses and seminars. More than 300 exercises are included with a selected hint set. The book starts with a broad introduction to the field and progresses to advanced results. Contents include: definition of Turing machines and basic time and space complexity classes, probabilistic algorithms, interactive proofs, cryptography, quantum computation, lower bounds for concrete computational models (decision trees, communication complexity, constant depth, algebraic and monotone circuits, proof complexity), average-case complexity and hardness amplification, derandomization and pseudorandom constructions, and the PCP theorem.

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