Probability And Computing Mitzenmacher Upfal Solutions

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High-Dimensional Statistics

These are my lecture notes from CS681: Design and Analysis of Algo rithms, a one-semester graduate course I taught at Cornell for three consec utive fall semesters from '88 to '90. The course serves a dual purpose: to cover core material in algorithms for graduate students in computer science preparing for their PhD qualifying exams, and to introduce theory students to some advanced topics in the design and analysis of algorithms. The material is thus a mixture of core and advanced topics. At first I meant these notes to supplement and not supplant a textbook, but over the three years they gradually took on a life of their own. In addition to the notes, I depended heavily on the texts • A. V. Aho, J. E. Hopcroft, and J. D. Ullman, The Design and Analysis of Computer Algorithms. Addison-Wesley, 1975. • M. R. Garey and D. S. Johnson, Computers and Intractibility: A Guide to the Theory of NP-Completeness. w. H. Freeman, 1979. • R. E. Tarjan, Data Structures and Network Algorithms. SIAM Regional Conference Series in Applied Mathematics 44, 1983. and still recommend them as excellent references.

Random Walks and Electric Networks

Some of the hardest computational problems have been successfully attacked through the use of probabilistic algorithms, which have an element of randomness to them. Concepts from the field of probability are also increasingly useful in analyzing the performance of algorithms, broadening our understanding beyond that provided by the worst-case or average-case analyses. This book surveys both of these emerging areas on the interface of the mathematical sciences and computer science. It is designed to attract new researchers to this area and

provide them with enough background to begin explorations of their own.

Discrete Probability Models and Methods

The role of probability in computer science has been growing for years and, in lieu of a tailored textbook, many courses have employed a variety of similar, but not entirely applicable, alternatives. To meet the needs of the computer science graduate student (and the advanced undergraduate), best-selling author Sheldon Ross has developed the premier probability text for aspiring computer scientists involved in computer simulation and modeling. The math is precise and easily understood. As with his other texts, Sheldon Ross presents very clear explanations of concepts and covers those probability models that are most in demand by, and applicable to, computer science and related majors and practitioners. Many interesting examples and exercises have been chosen to illuminate the techniques presented Examples relating to bin packing, sorting algorithms, the find algorithm, random graphs, self-organising list problems, the maximum weighted independent set problem, hashing, probabilistic verification, max SAT problem, queuing networks, distributed workload models, and many othersMany interesting examples and exercises have been chosen to illuminate the techniques presented

Probability and Algorithms

This book constitutes the refereed proceedings of the 5th International Workshop on Algorithms and Models for the Web-Graph, WAW 2007, held in San Diego, CA, USA, in December 2007 - colocated with WINE 2007, the Third International Workshop on Internet and Network Economics. The 13 revised full papers and five revised short papers presented were carefully reviewed and selected from a large pool of submissions for inclusion in the book. The papers address a wide variety of topics.

The Design and Analysis of Algorithms

Algorithmic design, especially for hard problems, is more essential for success in solving them than any standard improvement of current computer tech nologies. Because of this, the design of algorithms for solving hard problems is the core of current algorithmic research from the theoretical point of view as well as from the practical point of view. There are many general text books on algorithmics, and several specialized books devoted to particular approaches such as local search, randomization, approximation algorithms, or heuristics. But there is no textbook that focuses on the design of algorithms for hard computing tasks, and that systematically explains, combines, and compares the main possibilities for attacking hard algorithmic problems. As this topic is fundamental for computer science, this book tries to close this gap. Another motivation, and probably the main reason for writing this book, is connected to education. The considered area has developed very dynami cally in recent years and the research on this topic discovered several profound results, new concepts, and new methods. Some of the achieved contributions are so fundamental that one can speak about paradigms which should be in cluded in the education of every computer science student. Unfortunately, this is very far from reality. This is because these paradigms are not

sufficiently known in the computer science community, and so they are insufficiently com municated to students and practitioners.

Notes on Randomized Algorithms

Aimed at undergraduate mathematics and computer science students, this book is an excellent introduction to a lot of problems of discrete mathematics. It discusses a number of selected results and methods, mostly from areas of combinatorics and graph theory, and it uses proofs and problem solving to help students understand the solutions to problems. Numerous examples, figures, and exercises are spread throughout the book.

Probabilistic Methods for Algorithmic Discrete Mathematics

Probabilistic Analysis of Algorithms begins with a presentation of the "tools of the trade" currently used in probabilistic analyses, and continues with an applications section in which these tools are used in the analysis ofr selected algorithms. The tools section of the book provides the reader with an arsenal of analytic and numeric computing methods which are then applied to several groups of algorithms to analyze their running time or storage requirements characteristics. Topics covered in the applications section include sorting, communications network protocols and bin packing. While the discussion of the various algorithms is sufficient to motivate their structure, the emphasis throughout is on the probabilistic estimation of their operation under distributional assumptions on their input. Probabilistic Analysis of Algorithms assumes a working knowledge of engineering mathematics, drawing on real and complex analysis, combinatorics and probability theory. While the book is intended primarily as a text for the upper undergraduate and graduate student levels, it contains a wealth of material and should also prove an important reference for researchers. As such it is addressed to computer scientists, mathematicians, operations researchers, and electrical and industrial engineers who are interested in evaluating the probable operation of algorithms, rather than their worst-case behavior.

Probabilistic Analysis of Algorithms

Systematically teaches key paradigmic algorithm design methods Provides a deep insight into randomization

Computational Complexity

The problems of constructing covering codes and of estimating their parameters are the main concern of this book. It provides a unified account of the most recent theory of covering codes and shows how a number of mathematical and engineering issues are related to covering problems. Scientists involved in discrete mathematics, combinatorics, computer science, information theory, geometry, algebra or number theory will find the book of particular significance. It is designed both as an introductory textbook for the beginner and as a reference book for the expert mathematician and engineer. A number of unsolved problems suitable for research projects are also discussed.

Probability Models for Computer Science

Property testing algorithms are ultra"-efficient algorithms that decide whether a given object (e.g., a graph) has a certain property (e.g., bipartiteness), or is significantly different from any object that has the property. To this end property testing algorithms are given the ability to perform (local) queries to the input, though the decisions they need to make usually concern properties with a global nature. In the last two decades, property testing algorithms have been designed for many types of objects and properties, amongst them, graph properties, algebraic properties, geometric properties, and more. In this article we survey results in property testing, where our emphasis is on common analysis and algorithmic techniques. Among the techniques surveyed are the following: a) The self-correcting approach, which was mainly applied in the study of property testing of algebraic properties; b) The enforce and test approach, which was applied quite extensively in the analysis of algorithms for testing graph properties (in the dense-graphs model), as well as in other contexts; c) Szemeredi's Regularity Lemma, which plays a very important role in the analysis of algorithms for testing graph properties (in the dense-graphs model); d) The approach of Testing by implicit learning, which implies efficient testability of membership in many functions classes. e) Algorithmic techniques for testing properties of sparse graphs, which include local search and random walks.

Automated Deduction - CADE-21

"This textbook is designed to accompany a one- or two-semester course for advanced undergraduates or beginning graduate students in computer science and applied mathematics. - It gives an excellent introduction to the probabilistic techniques and paradigms used in the development of probabilistic algorithms and analyses. - It assumes only an elementary background in discrete mathematics and gives a rigorous yet accessible treatment of the material, with numerous examples and applications."--Jacket.

Design and Analysis of Randomized Algorithms

The emphasis in this book is placed on general models (Markov chains, random fields, random graphs), universal methods (the probabilistic method, the coupling method, the Stein-Chen method, martingale methods, the method of types) and versatile tools (Chernoff's bound, Hoeffding's inequality, Holley's inequality) whose domain of application extends far beyond the present text. Although the examples treated in the book relate to the possible applications, in the communication and computing sciences, in operations research and in physics, this book is in the first instance concerned with theory. The level of the book is that of a beginning graduate course. It is self-contained, the prerequisites consisting merely of basic calculus (series) and basic linear algebra (matrices). The reader is not assumed to be trained in probability since the first chapters give in considerable detail the background necessary to understand the rest of the book.

Performance Modeling and Design of Computer Systems

An accessible account of the rich theory surrounding concentration inequalities in probability theory, with applications from machine learning and statistics to high-dimensional geometry. This book introduces key ideas and presents a detailed summary of the state-of-the-art in the area, making it ideal for independent learning and as a reference.

Graph Colouring and the Probabilistic Method

A veritable one-stop-shop for anyone looking to get up to speed on what is going down in the field of automated deduction right now. This book contains the refereed proceedings of the 21st International Conference on Automated Deduction, CADE-21, held in Bremen, Germany, in July 2007. The 28 revised full papers and 6 system descriptions presented were selected from 64 submissions. All current aspects of automated deduction are addressed, ranging from theoretical and methodological issues to presentation and evaluation of theorem provers and logical reasoning systems.

Discrete Mathematics

Over the past decade, many major advances have been made in the field of graph coloring via the probabilistic method. This monograph, by two of the best on the topic, provides an accessible and unified treatment of these results, using tools such as the Lovasz Local Lemma and Talagrand's concentration inequality.

Algorithmics for Hard Problems

Probability theory, like much of mathematics, is indebted to physics as a source of problems and intuition for solving these problems. Unfortunately, the level of abstraction of current mathematics often makes it difficult for anyone but an expert to appreciate this fact. Random Walks and electric networks looks at the interplay of physics and mathematics in terms of an example—the relation between elementary electric network theory and random walks —where the mathematics involved is at the college level.

Concentration Inequalities

The LNCS subline Advanced Research in Computing and Software Science, ARCoSS, has been established in cooperation with the European Association for Theoretical Computer Science, EATCS, and the community of the European Joint Conferences on Theory and Practice of Software, ETAPS. Starting out with the proceedings of the EATCS main conferences and the ETAPS conferences, ARCoSS is also open to other high-quality proceedings focusing on computing and software science. Embedded in the overall framework of LNCS, ARCoSS is scientifically supervised by the ARCoSS-subline series editors and advisory board and is published with its own distinctive cover. In parallel to the printed book, each new volume is published electronically in LNCS Online.

Randomized Algorithms

For many applications a randomized algorithm is either the simplest algorithm available, or the fastest, or both. This tutorial presents the basic concepts in the design and analysis of randomized algorithms. The first part of the book presents tools from probability theory and probabilistic analysis that are recurrent in algorithmic applications. Algorithmic examples are given to illustrate the use of each tool in a concrete setting. In the second part of the book, each of the seven chapters focuses on one important area of application of randomized algorithms: data structures; geometric algorithms; graph algorithms; number theory; enumeration; parallel algorithms; and on-line algorithms. A comprehensive and representative selection of the algorithms in these areas is also given. This book should prove invaluable as a reference for researchers and professional programmers, as well as for students.

Probability and Computing

Online decision making under uncertainty and time constraints represents one of the most challenging problems for robust intelligent agents. In an increasingly dynamic, interconnected, and real-time world, intelligent systems must adapt dynamically to uncertainties, update existing plans to accommodate new requests and events, and produce high-quality decisions under severe time constraints. Such online decision-making applications are becoming increasingly common: ambulance dispatching and emergency city-evacuation routing, for example, are inherently online decision-making problems; other applications include packet scheduling for Internet communications and reservation systems. This book presents a novel framework, online stochastic optimization, to address this challenge. This framework assumes that the distribution of future requests, or an approximation thereof, is available for sampling, as is the case in many applications that make either historical data or predictive models available. It assumes additionally that the distribution of future requests is independent of current decisions, which is also the case in a variety of applications and holds significant computational advantages. The book presents several online stochastic algorithms implementing the framework, provides performance guarantees, and demonstrates a variety of applications. It discusses how to relax some of the assumptions in using historical sampling and machine learning and analyzes different underlying algorithmic problems. And finally, the book discusses the framework's possible limitations and suggests directions for future research.

Foundations of Data Science

Notes on Randomized AlgorithmsBy James Aspnes

Computer Algorithms C++

Written with computer scientists and engineers in mind, this book brings queueing theory decisively back to computer science.

The Probabilistic Method

This book provides an introduction to the mathematical and algorithmic

foundations of data science, including machine learning, high-dimensional geometry, and analysis of large networks. Topics include the counterintuitive nature of data in high dimensions, important linear algebraic techniques such as singular value decomposition, the theory of random walks and Markov chains, the fundamentals of and important algorithms for machine learning, algorithms and analysis for clustering, probabilistic models for large networks, representation learning including topic modelling and non-negative matrix factorization, wavelets and compressed sensing. Important probabilistic techniques are developed including the law of large numbers, tail inequalities, analysis of random projections, generalization guarantees in machine learning, and moment methods for analysis of phase transitions in large random graphs. Additionally, important structural and complexity measures are discussed such as matrix norms and VC-dimension. This book is suitable for both undergraduate and graduate courses in the design and analysis of algorithms for data.

Randomization and Approximation Techniques in Computer Science

"This book presents a modern, category-theory-based approach to topology to supplement the more traditional algebraic topology graduate course"--

Covering Codes

This book constitutes the refereed proceedings of the Second International Workshop on Randomization and Approximation Techniques in Computer Science, RANDOM'98, held in Barcelona, Spain, in October 1998. The 26 revised full papers presented were carefully reviewed and selected for inclusion in the proceedings. Also included are three invited contributions. Among the topics addressed are graph computation, derandomization, pattern matching, computational geometry, approximation algorithms, search algorithms, sorting, and networking algorithms.

Algorithms and Models for the Web-Graph

A coherent introductory text from a groundbreaking researcher, focusing on clarity and motivation to build intuition and understanding.

Online Stochastic Combinatorial Optimization

Leave nothing to chance. This cliche embodies the common belief that ran domness has no place in carefully planned methodologies, every step should be spelled out, each i dotted and each t crossed. In discrete mathematics at least, nothing could be further from the truth. Introducing random choices into algorithms can improve their performance. The application of proba bilistic tools has led to the resolution of combinatorial problems which had resisted attack for decades. The chapters in this volume explore and celebrate this fact. Our intention was to bring together, for the first time, accessible discus sions of the disparate ways in which probabilistic ideas are enriching discrete mathematics. These discussions are aimed at mathematicians with a good combinatorial background but require only a passing acquaintance with the basic definitions in probability

(e.g. expected value, conditional probability). A reader who already has a firm grasp on the area will be interested in the original research, novel syntheses, and discussions of ongoing developments scattered throughout the book. Some of the most convincing demonstrations of the power of these tech niques are randomized algorithms for estimating quantities which are hard to compute exactly. One example is the randomized algorithm of Dyer, Frieze and Kannan for estimating the volume of a polyhedron. To illustrate these techniques, we consider a simple related problem. Suppose S is some region of the unit square defined by a system of polynomial inequalities: Pi (x. y) ~ o.

High-Dimensional Probability

Discrete optimization problems are everywhere, from traditional operations research planning (scheduling, facility location and network design); to computer science databases; to advertising issues in viral marketing. Yet most such problems are NP-hard; unless P = NP, there are no efficient algorithms to find optimal solutions. This book shows how to design approximation algorithms: efficient algorithms that find provably near-optimal solutions. The book is organized around central algorithmic techniques for designing approximation algorithms, including greedy and local search algorithms, dynamic programming, linear and semidefinite programming, and randomization. Each chapter in the first section is devoted to a single algorithmic technique applied to several different problems, with more sophisticated treatment in the second section. The book also covers methods for proving that optimization problems are hard to approximate. Designed as a textbook for graduate-level algorithm courses, it will also serve as a reference for researchers interested in the heuristic solution of discrete optimization problems.

Topology

This book constitutes the refereed proceedings of the 16th Annual European Symposium on Algorithms, ESA 2008, held in Karlsruhe, Germany, in September 2008 in the context of the combined conference ALGO 2008. The 67 revised full papers presented together with 2 invited lectures were carefully reviewed and selected: 51 papers out of 147 submissions for the design and analysis track and 16 out of 53 submissions in the engineering and applications track. The papers address all current subjects in algorithmics reaching from design and analysis issues of algorithms over to real-world applications and engineering of algorithms in various fields. Special focus is given to mathematical programming and operations research, including combinatorial optimization, integer programming, polyhedral combinatorics and network optimization.

Algorithms

High-dimensional probability offers insight into the behavior of random vectors, random matrices, random subspaces, and objects used to quantify uncertainty in high dimensions. Drawing on ideas from probability, analysis, and geometry, it lends itself to applications in mathematics, statistics, theoretical computer science, signal processing, optimization, and more. It is the first to integrate theory, key

tools, and modern applications of high-dimensional probability. Concentration inequalities form the core, and it covers both classical results such as Hoeffding's and Chernoff's inequalities and modern developments such as the matrix Bernstein's inequality. It then introduces the powerful methods based on stochastic processes, including such tools as Slepian's, Sudakov's, and Dudley's inequalities, as well as generic chaining and bounds based on VC dimension. A broad range of illustrations is embedded throughout, including classical and modern results for covariance estimation, clustering, networks, semidefinite programming, coding, dimension reduction, matrix completion, machine learning, compressed sensing, and sparse regression.

Probability and Computing

Randomized algorithms have become a central part of the algorithms curriculum, based on their increasingly widespread use in modern applications. This book presents a coherent and unified treatment of probabilistic techniques for obtaining high probability estimates on the performance of randomized algorithms. It covers the basic toolkit from the Chernoff–Hoeffding bounds to more sophisticated techniques like martingales and isoperimetric inequalities, as well as some recent developments like Talagrand's inequality, transportation cost inequalities and log-Sobolev inequalities. Along the way, variations on the basic theme are examined, such as Chernoff–Hoeffding bounds in dependent settings. The authors emphasise comparative study of the different methods, highlighting respective strengths and weaknesses in concrete example applications. The exposition is tailored to discrete settings sufficient for the analysis of algorithms, avoiding unnecessary measure-theoretic details, thus making the book accessible to computer scientists as well as probabilists and discrete mathematicians.

Algorithms - ESA 2008

The subject of these notes is counting and related topics, viewed from a computational perspective. A major theme of the book is the idea of accumulating information about a set of combinatorial structures by performing a random walk on those structures. These notes will be of value not only to teachers of postgraduate courses on these topics, but also to established researchers. For the first time this body of knowledge has been brought together in a single volume.

Information Security Applications

From classical foundations to modern theory, this comprehensive guide to probability interweaves mathematical proofs, historical context and detailed illustrative applications.

Concentration of Measure for the Analysis of Randomized Algorithms

The author team that established its reputation nearly twenty years ago with Fundamentals of Computer Algorithms offers this new title, available in both pseudocode and C++ versions. Ideal for junior/senior level courses in the analysis

of algorithms, this well-researched text takes a theoretical approach to the subject, creating a basis for more in-depth study and providing opportunities for hands-on learning. Emphasizing design technique, the text uses exciting, state-of-the-art examples to illustrate design strategies.

Pseudorandomness

An integrated and up-to-date treatment of applied stochastic processes and queueing theory, with an emphasis on time-averages and long-run behavior. Theory demonstrates practical effects, such as priorities, pooling of queues, and bottlenecks. Appropriate for senior/graduate courses in queueing theory in Operations Research, Computer Science, Statistics, or Industrial Engineering departments. (vs. Ross, Karlin, Kleinrock, Heyman)

Distributed Computing

This book constitutes the thoroughly refereed post-conference proceedings of the 10th International Workshop on Information Security Applications, WISA 2009, held in Busan, Korea, during August 25-27, 2009. The 27 revised full papers presented were carefully reviewed and selected from a total of 79 submissions. The papers are organized in topical sections on mutlimedia security, device security, HW implementation security, applied cryptography, side channel attacks, cryptograptanalysis, anonymity/authentication/access controll, and network security.

The Design of Approximation Algorithms

Algorithmic and Analysis Techniques in Property Testing

New and classical results in computational complexity, including interactive proofs, PCP, derandomization, and quantum computation. Ideal for graduate students.

Stochastic Modeling and the Theory of Queues

Praise for the Third Edition “Researchers of any kind of extremal combinatorics or theoretical computer science will welcome the new edition of this book.” - MAA Reviews Maintaining a standard of excellence that establishes The Probabilistic Method as the leading reference on probabilistic methods in combinatorics, the Fourth Edition continues to feature a clear writing style, illustrative examples, and illuminating exercises. The new edition includes numerous updates to reflect the most recent developments and advances in discrete mathematics and the connections to other areas in mathematics, theoretical computer science, and statistical physics. Emphasizing the methodology and techniques that enable problem-solving, The Probabilistic Method, Fourth Edition begins with a description of tools applied to probabilistic arguments, including basic techniques that use expectation and variance as well as the more advanced applications of martingales and correlation inequalities. The authors explore where probabilistic techniques have been applied successfully and also examine topical coverage such as

discrepancy and random graphs, circuit complexity, computational geometry, and derandomization of randomized algorithms. Written by two well-known authorities in the field, the Fourth Edition features: Additional exercises throughout with hints and solutions to select problems in an appendix to help readers obtain a deeper understanding of the best methods and techniques New coverage on topics such as the Local Lemma, Six Standard Deviations result in Discrepancy Theory, Property B, and graph limits Updated sections to reflect major developments on the newest topics, discussions of the hypergraph container method, and many new references and improved results The Probabilistic Method, Fourth Edition is an ideal textbook for upper-undergraduate and graduate-level students majoring in mathematics, computer science, operations research, and statistics. The Fourth Edition is also an excellent reference for researchers and combinatorists who use probabilistic methods, discrete mathematics, and number theory. Noga Alon, PhD, is Baumritter Professor of Mathematics and Computer Science at Tel Aviv University. He is a member of the Israel National Academy of Sciences and Academia Europaea. A coeditor of the journal Random Structures and Algorithms, Dr. Alon is the recipient of the Polya Prize, The Gödel Prize, The Israel Prize, and the EMET Prize. Joel H. Spencer, PhD, is Professor of Mathematics and Computer Science at the Courant Institute of New York University. He is the cofounder and coeditor of the journal Random Structures and Algorithms and is a Sloane Foundation Fellow. Dr. Spencer has written more than 200 published articles and is the coauthor of Ramsey Theory, Second Edition, also published by Wiley.

The Theory of Probability

Randomization and probabilistic techniques play an important role in modern computer science, with applications ranging from combinatorial optimization and machine learning to communication networks and secure protocols. This 2005 textbook is designed to accompany a one- or two-semester course for advanced undergraduates or beginning graduate students in computer science and applied mathematics. It gives an excellent introduction to the probabilistic techniques and paradigms used in the development of probabilistic algorithms and analyses. It assumes only an elementary background in discrete mathematics and gives a rigorous yet accessible treatment of the material, with numerous examples and applications. The first half of the book covers core material, including random sampling, expectations, Markov's inequality, Chevyshev's inequality, Chernoff bounds, the probabilistic method and Markov chains. The second half covers more advanced topics such as continuous probability, applications of limited independence, entropy, Markov chain Monte Carlo methods and balanced allocations. With its comprehensive selection of topics, along with many examples and exercises, this book is an indispensable teaching tool.

Counting, Sampling and Integrating: Algorithms and Complexity

A survey of pseudorandomness, the theory of efficiently generating objects that look random despite being constructed using little or no randomness. This theory has significance for areas in computer science and mathematics, including computational complexity, algorithms, cryptography, combinatorics,

communications, and additive number theory.