Chapter 4

Induction, Recursion, and Recurrences

4.1 Mathematical Induction

Smallest Counter-Examples

In Section 3.3, we saw one way of proving statements about infinite universes: we considered a "generic" member of the universe and derived the desired statement about that generic member. When our universe is the universe of integers, or is in a one-to-one correspondence with the integers, there is a second technique we can use.

Recall our our proof of Euclid's Division Theorem (Theorem 2.12), which says that for each pair (m, n) of positive integers, there are nonnegative integers q and r such that $m = nq + r$ and $0 \leq r < n$. For the purpose of a proof by contradiction, we assumed that the statement was false. Then we said the following. "Among all pairs (m, n) that make it false, choose the smallest m that makes it false. We cannot have $m < n$ because then the statement would be true with $q = 0$ and $r = m$, and we cannot have $m = n$ because then the statement is true with $q = 1$ and $r = 0$. This means $m - n$ is a positive number smaller than m. We assumed that m was the smallest value that made the theorem false, and so the theorem must be true for the pair $(m - n, n)$. Therefore, there must exist a q' and r' such that

$$m - n = q'n + r', \text{ with } 0 \leq r' < n.$$

This is $m = (q' + 1)n + r'$. Now, by setting $q = q' + 1$ and $r = r'$, we can satisfy the theorem for the pair (m, n), contradicting the assumption that the statement is false. Thus the only possibility is that the statement is true."

Focus on the sentences "This means $m - n$ is a positive number smaller than m. We assumed that m was the smallest value that made the theorem false, and so the theorem must be true for the pair $(m - n, n)$. Therefore, there must exist a q' and r' such that

$$m - n = q'n + r', \text{ with } 0 \leq r' < n.$$

Thus $m = (q' + 1)n + r'$." To analyze these sentences, let $p(m, n)$ denote the statement "there are nonnegative integers q and r with $0 \leq r < n$ such that $m = nq + r$." The quoted sentences

4 2 Recursion Recurrences And Induction

Mario Benedicty,Frank R. Sledge

4 2 Recursion Recurrences And Induction:

Algorithm Design: A Methodological Approach - 150 problems and detailed solutions Patrick Bosc,Marc Guyomard,Laurent Miclet,2023-01-31 A bestseller in its French edition this book is original in its construction and its success in the French market demonstrates its appeal It is based on three principles 1 An organization of the chapters by families of algorithms exhaustive search divide and conquer etc On the contrary there is no chapter devoted only to a systematic exposure of say algorithms on strings Some of these will be found in different chapters 2 For each family of algorithms an introduction is given to the mathematical principles and the issues of a rigorous design with one or two pedagogical examples 3 For the most part the book details 150 problems spanning seven families of algorithms For each problem a precise and progressive statement is given More importantly a complete solution is detailed with respect to the design principles that have been presented often some classical errors are pointed out Roughly speaking two thirds of the book is devoted to the detailed rational construction of the solutions **FUNDAMENTALS OF DISCRETE MATHEMATICAL STRUCTURES, THIRD EDITION** CHOWDHARY, K. R.,2015-01-02 This updated text now in its Third Edition continues to provide the basic concepts of discrete mathematics and its applications at an appropriate level of rigour The text teaches mathematical logic discusses how to work with discrete structures analyzes combinatorial approach to problem solving and develops an ability to create and understand mathematical models and algorithms essentials for writing computer programs Every concept introduced in the text is first explained from the point of view of mathematics followed by its relation to Computer Science In addition it offers excellent coverage of graph theory mathematical reasoning foundational material on set theory relations and their computer representation supported by a number of worked out examples and exercises to reinforce the students skill Primarily intended for undergraduate students of Computer Science and Engineering and Information Technology this text will also be useful for undergraduate and postgraduate students of Computer Applications New to this Edition Incorporates many new sections and subsections such as recurrence relations with constant coefficients linear recurrence relations with and without constant coefficients rules for counting and shorting Peano axioms graph connecting graph scanning algorithm lexicographic shorting chains antichains and order isomorphism complemented lattices isomorphic order sets cyclic groups automorphism groups Abelian groups group homomorphism subgroups permutation groups cosets and quotient subgroups Includes many new worked out examples definitions theorems exercises and GATE level MCQs with answers *Python Algorithms* Magnus Lie Hetland,2014-09-17 Python Algorithms Second Edition explains the Python approach to algorithm analysis and design Written by Magnus Lie Hetland author of Beginning Python this book is sharply focused on classical algorithms but it also gives a solid understanding of fundamental algorithmic problem solving techniques The book deals with some of the most important and challenging areas of programming and computer science in a highly readable manner It covers both algorithmic theory and programming practice demonstrating how theory is reflected

in real Python programs Well known algorithms and data structures that are built into the Python language are explained and the user is shown how to implement and evaluate others   Methods in Algorithmic Analysis Vladimir A. Dobrushkin,2016-03-09 Explores the Impact of the Analysis of Algorithms on Many Areas within and beyond Computer Science A flexible interactive teaching format enhanced by a large selection of examples and exercises Developed from the author s own graduate level course Methods in Algorithmic Analysis presents numerous theories techniques and methods used for analyzing algorithms It exposes students to mathematical techniques and methods that are practical and relevant to theoretical aspects of computer science After introducing basic mathematical and combinatorial methods the text focuses on various aspects of probability including finite sets random variables distributions Bayes theorem and Chebyshev inequality It explores the role of recurrences in computer science numerical analysis engineering and discrete mathematics applications The author then describes the powerful tool of generating functions which is demonstrated in enumeration problems such as probabilistic algorithms compositions and partitions of integers and shuffling He also discusses the symbolic method the principle of inclusion and exclusion and its applications The book goes on to show how strings can be manipulated and counted how the finite state machine and Markov chains can help solve probabilistic and combinatorial problems how to derive asymptotic results and how convergence and singularities play leading roles in deducing asymptotic information from generating functions The final chapter presents the definitions and properties of the mathematical infrastructure needed to accommodate generating functions Accompanied by more than 1 000 examples and exercises this comprehensive classroom tested text develops students understanding of the mathematical methodology behind the analysis of algorithms It emphasizes the important relation between continuous classical mathematics and discrete mathematics which is the basis of computer science   **The Bulletin of Mathematics Books** ,1992   Discrete Mathematics with Applications William Barnier,Jean B. Chan,1989 Designed to provide a strong mathematics background for computer science engineering and mathematics students Topics in the text are drawn from logic Boolean algebra combinatorics automata and graph theory A chapter on automata theory and formal languages is included along with programming notes using Pascal language constructions to show how programming and mathematics are related Logic is introduced briefly in chapter one and then expanded upon in chapter four   The Mathematical Method Murray Eisenberg,1996 This text includes an eclectic blend of math number theory analysis and algebra with logic as an extra   **Discrete Mathematics** Kenneth A. Ross,Charles R. B. Wright,1992 This third edition offers an introduction to discrete mathematics covering relations induction counting techniques logic and graphs More advanced topics of Boolean algebra and permutation groups are included and there are numerous examples to reinforce the material   **Discrete Mathematics with Applications** Susanna S. Epp,2004 Susanna Epp s DISCRETE MATHEMATICS THIRD EDITION provides a clear introduction to discrete mathematics Renowned for her lucid accessible prose Epp explains complex abstract concepts with clarity and precision This book presents not only the

major themes of discrete mathematics but also the reasoning that underlies mathematical thought Students develop the ability to think abstractly as they study the ideas of logic and proof While learning about such concepts as logic circuits and computer addition algorithm analysis recursive thinking computability automata cryptography and combinatorics students discover that the ideas of discrete mathematics underlie and are essential to the science and technology of the computer age Overall Epp s emphasis on reasoning provides students with a strong foundation for computer science and upper level mathematics courses **Data Structures and Abstractions with Java** Frank M. Carrano,2007 This book Includes generic data types as well as enumerations for each loops the interface Iterable the class Scanner assert statements and autoboxing and unboxing Amazon Schaum's Outline of Discrete Mathematics, Fourth Edition Seymour Lipschutz,Marc Lipson,2021-11-30 Study smarter and stay on top of your discrete mathematics course with the bestselling Schaum s Outline now with the NEW Schaum s app and website Schaum s Outline of Discrete Mathematics Fourth Edition is the go to study guide for more than 115 000 math majors and first and second year university students taking basic computer science courses With an outline format that facilitates quick and easy review Schaum s Outline of Discrete Mathematics Fourth Edition helps you understand basic concepts and get the extra practice you need to excel in these courses Coverage includes set theory relations functions and algorithms logic and propositional calculus techniques of counting advanced counting techniques recursion probability graph theory directed graphs binary trees properties of the integers languages automata machines finite state machines and Turning machines ordered sets and lattices and Boolean algebra Features NEW to this edition the new Schaum s app and website NEW to this edition 20 NEW problem solving videos online 467 solved problems and hundreds of additional practice problems Outline format to provide a concise guide to the standard college course in discrete mathematics Clear concise explanations of discrete mathematics concepts Expanded coverage of logic the rules of inference and basic types of proofs in mathematical reasoning Increased emphasis on discrete probability and aspects of probability theory and greater accessibility to counting techniques Logic chapter emphasizes the IF THEN and IF THEN ELSE sequencing that occurs in computer programming Computer arithmetic chapter covers binary and hexagon addition and multiplication Cryptology chapter includes substitution and RSA method Supports these major texts Discrete Mathematics and Its Applications Rosen and Discrete Mathematics Epp Appropriate for the following courses Introductory Discrete Mathematics and Discrete Mathematics *Discrete Mathematical Structures* Mario Benedicty,Frank R. Sledge,1987 Discrete Mathematics with Graph Theory Edgar G. Goodaire,Michael M. Parmenter,1998 Adopting a user friendly conversational and at times humorous style these authors make the principles and practices of discrete mathematics as much fun as possible while presenting comprehensive rigorous coverage Starts with a chapter Yes There Are Proofs and emphasizes how to do proofs throughout the text *Automata, Languages and Programming* ,2000 *Schaum's Outline of Theory and Problems of Discrete Mathematics* Seymour Lipschutz,Marc Lipson,2007 Collins IGCSE Chemistry provides

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Compiling LISP for Evaluation on a Tightly Coupled Multiprocessor W. Ludwell Harrison,University of Illinois at Urbana-Champaign. Center for Supercomputing Research and Development,1986 *Journal of Computer Resource Management* ,2004 **Introduction to Discrete Mathematics** James Bradley,1988 **Discrete Mathematics for Computing** John E. Munro,1992-07 DSP System Design presents the investigation of special type of IIR polyphase filter structures combined with frequency transformation techniques used for fast multi rate filtering and their application for custom fixed point implementation Detailed theoretical analysis of the polyphase IIR structure has been presented for two and three coefficients in the two path arrangement This was then generalized for arbitrary filter order and any number of paths The use of polyphase IIR structures in decimation and interpolation is being presented and performance assessed in terms of the number of calculations required for the given filter specification and the simplicity of implementation Specimen decimation filter designs to be used in Sigma Delta lowpass and bandpass A D converters are presented which prove to outperform other traditional approaches New frequency transformation types have been suggested for both real and complex situations A new exact multi point frequency transformation approach for arbitrary frequency choice has been suggested and evaluated Applying such transformations to the existing filter allows to change their frequency response in an intuitive manner without the need of re designing them thus simplifying the designer s job when the specification changes during the prototyping and testing A new bit flipping algorithm has been developed to aid in filter design where the coefficient word length is constraint Also the standard Downhill Simplex Method floating point was modified to operate with the constrained coefficient word length Performance of both these advances is being evaluated on a number of filter cases Novel decimation and interpolation structures have been proposed which can be implemented very efficiently These allow an arbitrary order IIR anti aliasing filter to operate at the lower rate of the decimator interpolator Similar structures for polyphase IIR decimator interpolator structures are being discussed too A new approach to digital filter design and implementation has been suggested which speeds up silicon implementation of designs developed in Matlab The Simulink block description is

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