

PROGRESS IN THEORETICAL COMPUTER SCIENCE



The Graph Isomorphism Problem

Its Structural Complexity

**Johannes Köbler
Uwe Schöning
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Birkhäuser

The Graph Isomorphism Problem Its Structural Complexity

V. Arvind, Sanjiva Prasad



The Graph Isomorphism Problem Its Structural Complexity:

The Graph Isomorphism Problem J. Köbler, U. Schöning, J. Torán, 2012-12-06 Recently a variety of results on the complexity status of the graph isomorphism problem has been obtained. These results belong to the so-called structural part of Complexity Theory. Our idea behind this book is to summarize such results which might otherwise not be easily accessible in the literature and also to give the reader an understanding of the aims and topics in Structural Complexity Theory in general. The text is basically self-contained; the only prerequisite for reading it is some elementary knowledge from Complexity Theory and Probability Theory. It can be used to teach a seminar or a monographic graduate course but also parts of it especially Chapter 1 provide a source of examples for a standard graduate course on Complexity Theory. Many people have helped us in different ways. In the process of writing this book. Especially we would like to thank V. Arvind, R. V. Book, E. May, Ordóñez and the referee who gave very constructive comments. This book project was especially made possible by a DAAD grant in the Acciones Integradas program. The third author has been supported by the ESPRIT project ALCOM II.

The Graph Isomorphism Problem Johannes Köbler, Uwe Schöning, Jacobo Torán, 1993-01-01 The graph isomorphism problem belongs to the part of Complexity Theory that focuses on the structure of complexity classes involved in the classification of computational problems and in the relations among them. It consists in deciding whether two given graphs are isomorphic, i.e. whether there is a bijective mapping from the nodes of one graph to the nodes of the second graph such that the edge connections are respected. It is a problem of considerable practical as well as theoretical importance that is as of now unresolved in the sense that no efficient algorithm for it has yet been found. Given this fact it is natural to ask whether such an algorithm exists at all or whether the problem is intractable. This book focuses on this issue and presents several recent results that provide a better understanding of the relative position of the graph isomorphism problem in the class NP as well as in other complexity classes. It also uses the problem to illustrate important concepts in structural complexity providing a look into the more general theory. The book is basically self-contained; the only prerequisite for reading it is some elementary knowledge from Complexity Theory and Probability Theory. Its level of presentation makes it eminently suitable for a seminar or graduate course devoted to the problem or as a rich source of examples for a standard graduate course in Complexity Theory. **Book cover** [The Graph Isomorphism Problem](#), 1993 *Structural Pattern Recognition using Graph Matching* Shri Prakash Dwivedi, Ravi Shankar Singh, 2025-09-30 This book presents a comprehensive exploration of structural pattern recognition with a clear understanding of graph representation and manipulation. It explains graph matching techniques, unearthing the core principles of graph similarity measures, subgraph isomorphism, and advanced algorithms tailored to various pattern recognition tasks. It bridges the gap between theory and application by providing case studies, hands-on examples, and applications. It is a reference book for academicians, researchers, and students working in the fields of structural pattern recognition, computer vision, artificial intelligence, and data science. Begins with the fundamentals of graph

theory graph matching algorithms and structural pattern recognition concepts and explains the principles methodologies and practical implementations Presents relevant case studies and hands on examples across chapters to guide making informed decisions by graph matching Discusses various graph matching algorithms including exact and approximate methods geometric methods spectral techniques graph kernels and graph neural networks including practical examples to illustrate the strengths and limitations of each approach Showcases the versatility of graph matching in real world applications such as image analysis biological molecule identification object recognition social network clustering and recommendation systems Describes deep learning models for graph matching including graph convolutional networks GCNs and graph neural networks GNNs

STACS 2000 Horst Reichel,Sophie Tison,2007-08-03 This book constitutes the refereed proceedings of the 17th Annual Symposium on Theoretical Aspects of Computer Science STACS 2000 held in Lille France in February 2000 The 51 revised full papers presented together with the three invited papers were carefully reviewed and selected from a total of 146 submissions on the basis of some 700 reviewers reports The papers address fundamental issues from all current areas of theoretical computer science including algorithms data structures automata formal languages complexity verification logic cryptography graph theory optimization etc

Mathematical Software - ICMS 2018 James H. Davenport,Manuel Kauers,George Labahn,Josef Urban,2018-07-17 This book constitutes the proceedings of the 6th International Conference on Mathematical Software ICMS 2018 held in South Bend IN USA in July 2018 The 59 papers included in this volume were carefully reviewed and selected from numerous submissions The program of the 2018 meeting consisted of 20 topical sessions each of which providing an overview of the challenges achievements and progress in a subeld of mathematical software research development and use

Propositional Logic Hans Kleine Büning,Theodor Lettmann,1999-08-28 This account of propositional logic concentrates on the algorithmic translation of important methods especially of decision procedures for subclasses of propositional logic Important classical results and a series of new results taken from the fields of normal forms satisfiability and deduction methods are arranged in a uniform and complete theoretic framework The algorithms presented can be applied to VLSI design deductive databases and other areas After introducing the subject the authors discuss satisfiability problems and satisfiability algorithms with complexity considerations the resolution calculus with different refinements and special features and procedures for Horn formulas Then a selection of further calculi and some results on the complexity of proof procedures are presented The last chapter is devoted to quantified boolean formulas The algorithmic approach will make this book attractive to computer scientists and graduate students in areas such as automated reasoning logic programming complexity theory and pure and applied logic

Gems of Theoretical Computer Science Uwe Schöning,Randall J. Pruim,2012-12-06 While I was visiting Boston University during the 1996 97 academic year I noticed a small book written in German on a shelf in Steve Homer s office Curious I borrowed it for my train ride home and began reading one of the chapters I liked the style and format of the book so much that over the course of the next few

months I frequently found myself reaching for it and working through one chapter or another This was my introduction to Peden der Theoretischen Informatik A few of my colleagues had also seen the book They also found it interesting but most of them did not read German well enough to read more than small portions of it enjoyably I hope that the English version will rectify this situation and that many will enjoy and learn from the English version as much as I enjoyed the German version The front matter of this book says that it has been translated revised and expanded I should perhaps say a few words about each of these tasks In translating the book I have tried as much as possible to retain the feel of the original which is somewhat less formal and impersonal than a typical text book yet relatively concise I certainly hope that the pleasure of the pursuit of understanding has not gotten lost in the translation

Applications of Generative AI Zhihan Lyu, 2024-03-05

This book provides a comprehensive introduction to Generative AI in terms of basic concepts core technologies technical architecture and application scenarios Readers gain a deeper understanding of the emerging discipline of Generative AI This book covers the latest cutting edge application technologies of Generative AI in various fields It provides relevant practitioners with ideas to solve problems and deepen their understanding of Generative AI At the same time it guides and helps Generative AI and related industries to deepen their understanding of the industry and enhance professional knowledge and skills Starting from reality this book lists many cases and analyzes theories in a popular image The book is useful for AI researchers and specifically for those working with the applications at hand primarily medical imaging and construction twinning industry It covers a variety of cutting edge technologies in Generative AI which provides researchers with new research ideas

The Algorithm Design Manual Steven S Skiena, 2009-04-05 This newly expanded and updated second edition of the best selling classic continues to take the mystery out of designing algorithms and analyzing their efficacy and efficiency Expanding on the first edition the book now serves as the primary textbook of choice for algorithm design courses while maintaining its status as the premier practical reference guide to algorithms for programmers researchers and students The reader friendly Algorithm Design Manual provides straightforward access to combinatorial algorithms technology stressing design over analysis The first part Techniques provides accessible instruction on methods for designing and analyzing computer algorithms The second part Resources is intended for browsing and reference and comprises the catalog of algorithmic resources implementations and an extensive bibliography NEW to the second edition Doubles the tutorial material and exercises over the first edition Provides full online support for lecturers and a completely updated and improved website component with lecture slides audio and video Contains a unique catalog identifying the 75 algorithmic problems that arise most often in practice leading the reader down the right path to solve them Includes several NEW war stories relating experiences from real world applications Provides up to date links leading to the very best algorithm implementations available in C C and Java

Algorithm Engineering Matthias Müller-Hannemann, Stefan Schirra, 2010-08-05 Algorithms are essential building blocks of computer applications However advancements in computer

hardware which render traditional computer models more and more unrealistic and an ever increasing demand for efficient solution to actual real world problems have led to a rising gap between classical algorithm theory and algorithmics in practice The emerging discipline of Algorithm Engineering aims at bridging this gap Driven by concrete applications Algorithm Engineering complements theory by the benefits of experimentation and puts equal emphasis on all aspects arising during a cyclic solution process ranging from realistic modeling design analysis robust and efficient implementations to careful experiments This tutorial outcome of a GI Dagstuhl Seminar held in Dagstuhl Castle in September 2006 covers the essential aspects of this process in ten chapters on basic ideas modeling and design issues analysis of algorithms realistic computer models implementation aspects and algorithmic software libraries selected case studies as well as challenges in Algorithm Engineering Both researchers and practitioners in the field will find it useful as a state of the art survey

Topics in Artificial Intelligence Associazione italiana per l'intelligenza artificiale. Congress, Marco Gori, Giovanni Soda, 1995-09-27 This book presents the refereed proceedings of the 4th Congress of the Italian Association for Artificial Intelligence AI IA 95 held in Florence Italy in October 1995 The 31 revised full papers and the 12 short presentations contained in the volume were selected from a total of 101 submissions on the basis of a careful reviewing process The papers are organized in sections on natural language processing fuzzy systems machine learning knowledge representation automated reasoning cognitive models robotics and planning connectionist models model based reasoning and distributed artificial intelligence

Neural Networks and Analog Computation Hava T. Siegelmann, 2012-12-06 Humanity's most basic intellectual quest to decipher nature and master it has led to numerous efforts to build machines that simulate the world or communicate with it Bus70 Tur36 MP43 Sha48 vN56 Sha41 Rub89 NK91 Nyc92 The computational power and dynamic behavior of such machines is a central question for mathematicians computer scientists and occasionally physicists Our interest is in computers called artificial neural networks In their most general framework neural networks consist of assemblies of simple processors or neurons each of which computes a scalar activation function of its input This activation function is nonlinear and is typically a monotonic function with bounded range much like neural responses to input stimuli The scalar value produced by a neuron affects other neurons which then calculate a new scalar value of their own This describes the dynamical behavior of parallel updates Some of the signals originate from outside the network and act as inputs to the system while other signals are communicated back to the environment and are thus used to encode the end result of the computation

Advancing Uncertain Combinatorics through Graphization, Hyperization, and Uncertainization: Fuzzy, Neutrosophic, Soft, Rough, and Beyond Takaaki Fujita, Florentin Smarandache, 2025-01-20 This book is the fifth volume in the series of Collected Papers on Advancing Uncertain Combinatorics through Graphization Hyperization and Uncertainization Fuzzy Neutrosophic Soft Rough and Beyond This volume specifically delves into the concept of Various SuperHyperConcepts building on the foundational advancements introduced in previous volumes The series aims to explore

the ongoing evolution of uncertain combinatorics through innovative methodologies such as graphization hyperization and uncertainization These approaches integrate and extend core concepts from fuzzy neutrosophic soft and rough set theories providing robust frameworks to model and analyze the inherent complexity of real world uncertainties At the heart of this series lies combinatorics and set theory cornerstones of mathematics that address the study of counting arrangements and the relationships between collections under defined rules Traditionally combinatorics has excelled in solving problems involving uncertainty while advancements in set theory have expanded its scope to include powerful constructs like fuzzy and neutrosophic sets These advanced sets bring new dimensions to uncertainty modeling by capturing not just binary truth but also indeterminacy and falsity In this fifth volume the exploration of Various SuperHyperConcepts provides an innovative lens to address uncertainty complexity and hierarchical relationships It synthesizes key methodologies introduced in earlier volumes such as hyperization and neutrosophic extensions while advancing new theories and applications From pioneering hyperstructures to applications in advanced decision making language modeling and neural networks this book represents a significant leap forward in uncertain combinatorics and its practical implications across disciplines The book is structured into 17 chapters each contributing unique perspectives and advancements in the realm of Various SuperHyperConcepts and their related frameworks Chapter 1 introduces the concept of Body Mind Soul Spirit Fluidity within psychology and phenomenology while examining established social science frameworks like PDCA and DMAIC It extends these frameworks using Neutrosophic Sets a flexible extension of Fuzzy Sets to improve their adaptability for mathematical and programming applications The chapter emphasizes the potential of Neutrosophic theory to address multi dimensional challenges in social sciences Chapter 2 delves into the theoretical foundation of Hyperfunctions and their generalizations such as Hyperrandomness and Hyperdecision Making It explores higher order frameworks like Weak Hyperstructures Hypergraphs and Cognitive Hypermaps aiming to establish their versatility in addressing multi layered problems and setting a foundation for further studies Chapter 3 extends traditional decision making methodologies into HyperDecision Making and n SuperHyperDecision Making By building on approaches like MCDM and TOPSIS this chapter develops frameworks capable of addressing complex decision making scenarios emphasizing their applicability in dynamic multi objective contexts Chapter 4 explores integrating uncertainty frameworks including Fuzzy Neutrosophic and Plithogenic Sets into Large Language Models LLMs It proposes innovative models like Large Uncertain Language Models and Natural Uncertain Language Processing integrating hierarchical and generalized structures to advance the handling of uncertainty in linguistic representation and processing Chapter 5 introduces the Natural n Superhyper Plithogenic Language by synthesizing natural language plithogenic frameworks and superhyperstructures This innovative construct seeks to address challenges in advanced linguistic and structural modeling blending attributes of uncertainty complexity and hierarchical abstraction Chapter 6 defines mathematical extensions such as NeutroHyperstructures and AntiHyperstructures using the Neutrosophic

Triplet framework It formalizes structures like neutro superhyperstructures advancing classical frameworks into higher dimensional realms Chapter 7 explores the extension of Binary Code Gray Code and Floorplans through hyperstructures and superhyperstructures It highlights their iterative and hierarchical applications demonstrating their adaptability for complex data encoding and geometric arrangement challenges Chapter 8 investigates the Neutrosophic TwoFold SuperhyperAlgebra combining classical algebraic operations with neutrosophic components This chapter expands upon existing algebraic structures like Hyperalgebra and AntiAlgebra exploring hybrid frameworks for advanced mathematical modeling Chapter 9 introduces Hyper Z Numbers and SuperHyper Z Numbers by extending the traditional Z Number framework with hyperstructures These extensions aim to represent uncertain information in more complex and multidimensional contexts Chapter 10 revisits category theory through the lens of hypercategories and superhypercategories By incorporating hierarchical and iterative abstractions this chapter extends the foundational principles of category theory to more complex and layered structures Chapter 11 formalizes the concept of n SuperHyperBranch width and its theoretical properties By extending hypergraphs into superhypergraphs the chapter explores recursive structures and their potential for representing intricate hierarchical relationships Chapter 12 examines superhyperstructures of partitions integrals and spaces proposing a framework for advancing mathematical abstraction It highlights the potential applications of these generalizations in addressing hierarchical and multi layered problems Chapter 13 revisits Rough HyperRough and SuperHyperRough Sets introducing new concepts like Tree HyperRough Sets The chapter connects these frameworks to advanced approaches for modeling uncertainty and complex relationships Chapter 14 explores Plithogenic SuperHyperStructures and their applications in decision making control and neuro systems By integrating these advanced frameworks the chapter proposes innovative directions for extending existing systems to handle multi attribute and contradictory properties Chapter 15 focuses on superhypergraphs expanding hypergraph concepts to model complex structural types like arboreal and molecular superhypergraphs It introduces Generalized n th Powersets as a unifying framework for broader mathematical applications while also touching on hyperlanguage processing Chapter 16 defines NeutroHypergeometry and AntiHypergeometry as extensions of classical geometric structures Using the Geometric Neutrosophic Triplet the chapter demonstrates the flexibility of these frameworks in representing multi dimensional and uncertain relationships Chapter 17 establishes the theoretical groundwork for SuperHyperGraph Neural Networks and Plithogenic Graph Neural Networks By integrating advanced graph structures this chapter opens pathways for applying neural networks to more intricate and uncertain data representations

Classification Algorithms for Codes and Designs Petteri Kaski, Patric R.J. Östergård, 2006-02-03 A new starting point and a new method are requisite to insure a complete classification of the Steiner triple systems of order 15 This method was furnished and its tedious and difficult execution undertaken by Mr Cole F N Cole L D Cummings and H S White 1917 129 The history of classifying combinatorial objects is as old as the history of the objects themselves In the mid 19th

century Kirkman Steiner and others became the fathers of modern combinatorics and their work on various objects including what became later known as Steiner triple systems led to several classification results Almost a century earlier in 1782 Euler 180 published some results on classifying small Latin squares but for the first few steps in this direction one should actually go at least as far back as ancient Greece and the proof that there are exactly five Platonic solids One of the most remarkable achievements in the early pre computer era is the classification of the Steiner triple systems of order 15 quoted above An onerous task that today no sensible person would attempt by hand calculation Because with the exception of occasional parameters for which combinatorial arguments are effective often to prove nonexistence or uniqueness classification in general is about algorithms and computation

Solving Higher-Order Equations Christian Prehofer, 1998 This monograph develops techniques for equational reasoning in higher order logic Due to its expressiveness higher order logic is used for specification and verification of hardware software and mathematics In these applications higher order logic provides the necessary level of abstraction for concise and natural formulations The main assets of higher order logic are quantification over functions or predicates and its abstraction mechanism These allow one to represent quantification in formulas and other variable binding constructs In this book we focus on equational logic as a fundamental and natural concept in computer science and mathematics We present calculi for equational reasoning modulo higher order equations presented as rewrite rules This is followed by a systematic development from general equational reasoning towards effective calculi for declarative programming in higher order logic and A calculus This aims at integrating and generalizing declarative programming models such as functional and logic programming In these two prominent declarative computation models we can view a program as a logical theory and a computation as a deduction

Algorithms on Trees and Graphs Gabriel Valiente, 2013-04-17 Graph algorithms is a well established subject in mathematics and computer science Beyond classical application fields like approximation combinatorial optimization graphics and operations research graph algorithms have recently attracted increased attention from computational molecular biology and computational chemistry Centered around the fundamental issue of graph isomorphism this text goes beyond classical graph problems of shortest paths spanning trees flows in networks and matchings in bipartite graphs Advanced algorithmic results and techniques of practical relevance are presented in a coherent and consolidated way This book introduces graph algorithms on an intuitive basis followed by a detailed exposition in a literate programming style with correctness proofs as well as worst case analyses Furthermore full C implementations of all algorithms presented are given using the LEDA library of efficient data structures and algorithms Numerous illustrations examples and exercises and a comprehensive bibliography support students and professionals in using the book as a text and source of reference

Handbook of Knowledge Representation Frank van Harmelen, Vladimir Lifschitz, Bruce Porter, 2008-01-08 Handbook of Knowledge Representation describes the essential foundations of Knowledge Representation which lies at the core of Artificial Intelligence AI The book provides an up to date review of twenty five key

topics in knowledge representation written by the leaders of each field It includes a tutorial background and cutting edge developments as well as applications of Knowledge Representation in a variety of AI systems This handbook is organized into three parts Part I deals with general methods in Knowledge Representation and reasoning and covers such topics as classical logic in Knowledge Representation satisfiability solvers description logics constraint programming conceptual graphs nonmonotonic reasoning model based problem solving and Bayesian networks Part II focuses on classes of knowledge and specialized representations with chapters on temporal representation and reasoning spatial and physical reasoning reasoning about knowledge and belief temporal action logics and nonmonotonic causal logic Part III discusses Knowledge Representation in applications such as question answering the semantic web automated planning cognitive robotics multi agent systems and knowledge engineering This book is an essential resource for graduate students researchers and practitioners in knowledge representation and AI Make your computer smarter Handle qualitative and uncertain information Improve computational tractability to solve your problems easily

FSTTCS 2007: Foundations of Software Technology and Theoretical Computer Science V. Arvind, Sanjiva Prasad, 2007-11-22 This book constitutes the refereed proceedings of the 27th International Conference on the Foundations of Software Technology and Theoretical Computer Science FSTTCS 2007 held in New Delhi India in December 2007 The 40 revised full papers presented together with 5 invited papers were carefully reviewed and selected from 135 submissions The papers provide original research results in fundamental aspects of computer science as well as reports from the frontline of software technology and theoretical computer science A broad variety of current topics from the theory of computing are addressed ranging from software science programming theory systems design and analysis formal methods mathematical logic mathematical foundations discrete mathematics combinatorial mathematics complexity theory and automata theory to theoretical computer science in general

Nondeterminism in Algebraic Specifications and Algebraic Programs Hussmann, 2013-03-08 Algebraic specification nondeterminism and term rewriting are three active research areas aiming at concepts for the abstract description of software systems Algebraic specifications are well suited for describing data structures and sequential software systems in an abstract way Term rewriting methods are used in many prototyping systems and form the basis for executing specifications Nondeterminism plays a major role in formal language theory in programming it serves for delaying design decisions in program development and occurs in a natural way in formalisations of distributed processes Heinrich Hussmann presents an elegant extension of equational specification and term rewriting to include nondeterminism Based on a clean model-theoretic semantics he considers term rewriting systems without confluence restrictions as a specification language and shows that fundamental properties such as the existence of initial models or the soundness and completeness of narrowing the basic mechanism for executing equational specifications can be extended to nondeterministic computations The work of Heinrich Hussmann is an excellent contribution to Algebraic Programming it gives a framework that admits a

direct approach to program verification is suitable for describing concurrent and distributed processes and it can be executed as fast as Prolog

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