

Algorithms  
and Computation  
in Mathematics

Volume 21

Dmitry Kozlov

# Combinatorial Algebraic Topology



Springer

# Combinatorial Algebraic Topology Algorithms And Computation In Mathematics

**Graham Ellis**



## **Combinatorial Algebraic Topology Algorithms And Computation In Mathematics:**

**Combinatorial Algebraic Topology** Dmitry Kozlov, 2008-01-08 This volume is the first comprehensive treatment of combinatorial algebraic topology in book form The first part of the book constitutes a swift walk through the main tools of algebraic topology Readers graduate students and working mathematicians alike will probably find particularly useful the second part which contains an in depth discussion of the major research techniques of combinatorial algebraic topology Although applications are sprinkled throughout the second part they are principal focus of the third part which is entirely devoted to developing the topological structure theory for graph homomorphisms **Connection Matrices in**

**Combinatorial Topological Dynamics** Marian Mrozek, Thomas Wanner, 2025-07-08 This book provides an introduction to the theory of connection matrices in the context of combinatorial multivector fields The theory of connection matrices was proposed by Conley and Franzosa for classical continuous time dynamical systems as a tool for studying connecting orbits between isolated invariant sets It generalizes the Morse complex in Morse theory and has found numerous applications in dynamics Connection matrices have been and still are a challenging topic to study as there are no complete introductory texts and both their intricate definition and properties are scattered over numerous research papers In recent years dynamical concepts have found their way into a combinatorial context Starting with combinatorial vector fields introduced by Forman to generalize classical Morse theory it has been realized that this transfer of ideas can lead to important applications Similarly Conley s theory of isolated invariant sets has been transferred to the combinatorial setting This when combined with the concept of multivector fields opens the door to a complete combinatorial dynamical theory In this book we take Conley s theory one step further by presenting a complete discussion of connection matrices for combinatorial multivector fields While some of the results in this book are based on known approaches we show in a detailed way how they can be carried over to the case of multivector fields on general Lefschetz complexes Along the way we introduce notions which are new even in the classical setting such as a formal approach to addressing the nonuniqueness of connection matrices as well as mechanisms for comparing connection matrices even under poset changes Finally we show that specifically for the case of Forman s gradient combinatorial vector fields connection matrices are necessarily unique and can be determined explicitly in a straightforward way Focusing on the combinatorial theory of connection matrices has a number of advantages On the one hand many of the technical difficulties of the classical continuous time dynamics situation are not present in the discrete combinatorial context This allows us to provide a complete and informal introduction to the theory in the second section of the book This in turn will enable the readers to construct and analyze their own examples easily On the other hand the complete theory including the existence of connecting orbits in the combinatorial setting can be presented in detail based on an explicit distinction between the algebraic and topological parts of the theory In this way it is our hope that this book will be an impetus for further knowledge transfer between dynamics and combinatorics and even topological data analysis This

text is aimed at researchers in the fields of dynamics and topological data analysis and it is suitable for advanced graduate students interested in applying connection matrix methods to their own studies

**Directed Algebraic Topology and Concurrency** Lisbeth Fajstrup, Eric Goubault, Emmanuel Haucourt, Samuel Mimram, Martin Raussen, 2016-03-02 This monograph presents an application of concepts and methods from algebraic topology to models of concurrent processes in computer science and their analysis Taking well known discrete models for concurrent processes in resource management as a point of departure the book goes on to refine combinatorial and topological models In the process it develops tools and invariants for the new discipline directed algebraic topology which is driven by fundamental research interests as well as by applications primarily in the static analysis of concurrent programs The state space of a concurrent program is described as a higher dimensional space the topology of which encodes the essential properties of the system In order to analyse all possible executions in the state space more than just the topological properties have to be considered Execution paths need to respect a partial order given by the time flow As a result tools and concepts from topology have to be extended to take privileged directions into account The target audience for this book consists of graduate students researchers and practitioners in the field mathematicians and computer scientists alike

[An Invitation to Computational Homotopy](#) Graham Ellis, 2019 An Invitation to Computational Homotopy is an introduction to elementary algebraic topology for those with an interest in computers and computer programming It expertly illustrates how the basics of the subject can be implemented on a computer through its focus on fully worked examples designed to develop problem solving techniques The transition from basic theory to practical computation raises a range of non trivial algorithmic issues which will appeal to readers already familiar with basic theory and who are interested in developing computational aspects The book covers a subset of standard introductory material on fundamental groups covering spaces homology cohomology and classifying spaces as well as some less standard material on crossed modules These topics are covered in a way that hints at potential applications of topology in areas of computer science and engineering outside the usual territory of pure mathematics and also in a way that demonstrates how computers can be used to perform explicit calculations within the domain of pure algebraic topology itself The initial chapters include in depth examples from data mining biology and digital image analysis while the later chapters cover a range of computational examples on the cohomology of classifying spaces that are likely beyond the reach of a purely paper and pen approach to the subject An Invitation to Computational Homotopy serves as a self contained and informal introduction to these topics and their implementation in the sphere of computer science Written in a dynamic and engaging style it skilfully showcases a range of useful machine computations and will serve as an invaluable aid to graduate students working with algebraic topology

**Research in Computational Topology 2** Ellen Gasparovic, Vanessa Robins, Katharine Turner, 2022-05-10 This second volume of Research in Computational Topology is a celebration and promotion of research by women in applied and computational topology containing the proceedings of the second workshop for Women in

Computational Topology WinCompTop as well as papers solicited from the broader WinCompTop community The multidisciplinary and international WinCompTop workshop provided an exciting and unique opportunity for women in diverse locations and research specializations to interact extensively and collectively contribute to new and active research directions in the field The prestigious senior researchers that signed on to head projects at the workshop are global leaders in the discipline and two of them were authors on some of the first papers in the field Some of the featured topics include topological data analysis of power law structure in neural data a nerve theorem for directional graph covers topological or homotopical invariants for directed graphs encoding connections among a network of neurons and the issue of approximation of objects by digital grids including precise relations between the persistent homology of dual cubical complexes *The Mathematics of Data* Michael W. Mahoney, John C. Duchi, Anna C. Gilbert, 2018-11-15 Nothing provided **Pattern Recognition on Oriented Matroids** Andrey O. Matveev, 2017-09-11 Pattern Recognition on Oriented Matroids covers a range of innovative problems in combinatorics poset and graph theories optimization and number theory that constitute a far reaching extension of the arsenal of committee methods in pattern recognition The groundwork for the modern committee theory was laid in the mid 1960s when it was shown that the familiar notion of solution to a feasible system of linear inequalities has ingenious analogues which can serve as collective solutions to infeasible systems A hierarchy of dialects in the language of mathematics for instance open cones in the context of linear inequality systems regions of hyperplane arrangements and maximal covectors or tope of oriented matroids provides an excellent opportunity to take a fresh look at the infeasible system of homogeneous strict linear inequalities the standard working model for the contradictory two class pattern recognition problem in its geometric setting The universal language of oriented matroid theory considerably simplifies a structural and enumerative analysis of applied aspects of the infeasibility phenomenon The present book is devoted to several selected topics in the emerging theory of pattern recognition on oriented matroids the questions of existence and applicability of matroidal generalizations of committee decision rules and related graph theoretic constructions to oriented matroids with very weak restrictions on their structural properties a study in which in particular interesting subsequences of the Farey sequence appear naturally of the hierarchy of the corresponding tope committees a description of the three tope committees that are the most attractive approximation to the notion of solution to an infeasible system of linear constraints an application of convexity in oriented matroids as well as blocker constructions in combinatorial optimization and in poset theory to enumerative problems on tope committees an attempt to clarify how elementary changes one element reorientations in an oriented matroid affect the family of its tope committees a discrete Fourier analysis of the important family of critical tope committees through rank and distance relations in the tope poset and the tope graph the characterization of a key combinatorial role played by the symmetric cycles in hypercube graphs Contents Oriented Matroids the Pattern Recognition Problem and Tope Committees Boolean Intervals Dehn Sommerville Type Relations Farey

Subsequences Blocking Sets of Set Families and Absolute Blocking Constructions in Posets Committees of Set Families and Relative Blocking Constructions in Posets Layers of Tope Committees Three Tope Committees Halfspaces Convex Sets and Tope Committees Tope Committees and Reorientations of Oriented Matroids Topes and Critical Committees Critical Committees and Distance Signals Symmetric Cycles in the Hypercube Graphs      **Morse Theory: Smooth And Discrete** Kevin P Knudson, 2015-05-29 Morse Theory Smooth and Discrete serves as an introduction to classical smooth Morse theory and to Forman's discrete Morse theory highlighting the parallels between the two subjects This is the first time both smooth and discrete Morse theory have been treated in a single volume This makes the book a valuable resource for students and professionals working in topology and discrete mathematics With a strong focus on examples the text is suitable for advanced undergraduates or beginning graduate students      **Graph Theory** Beril Sirmacek, 2018-01-31 This book is prepared as a combination of the manuscripts submitted by respected mathematicians and scientists around the world As an editor I truly enjoyed reading each manuscript Not only will the methods and explanations help you to understand more about graph theory but I also hope you will find it joyful to discover ways that you can apply graph theory in your scientific field I believe the book can be read from the beginning to the end at once However the book can also be used as a reference guide in order to turn back to it when it is needed I have to mention that this book assumes the reader to have a basic knowledge about graph theory The very basics of the theory and terms are not explained at the beginner level I hope this book will support many applied and research scientists from different scientific fields      **Algebraic Foundations for Applied Topology and Data Analysis** Hal Schenck, 2022-11-21 This book gives an intuitive and hands on introduction to Topological Data Analysis TDA Covering a wide range of topics at levels of sophistication varying from elementary matrix algebra to esoteric Grothendieck spectral sequence it offers a mirror of data science aimed at a general mathematical audience The required algebraic background is developed in detail The first third of the book reviews several core areas of mathematics beginning with basic linear algebra and applications to data fitting and web search algorithms followed by quick primers on algebra and topology The middle third introduces algebraic topology along with applications to sensor networks and voter ranking The last third covers key contemporary tools in TDA persistent and multiparameter persistent homology Also included is a user's guide to derived functors and spectral sequences useful but somewhat technical tools which have recently found applications in TDA and an appendix illustrating a number of software packages used in the field Based on a course given as part of a masters degree in statistics the book is appropriate for graduate students

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