

Algebraic combinatorial geometry: the polynomial method in arithmetic combinatorics, incidence combinatorics, and number theory

Terence Tao*

Arithmetic combinatorics is often concerned with the problem of controlling the possible range of behaviours of arbitrary finite sets in a group or ring with respect to arithmetic operations such as addition or multiplication. Similarly, combinatorial geometry is often concerned with the problem of controlling the possible range of behaviours of arbitrary finite collections of geometric objects such as points, lines, or circles with respect to geometric operations such as incidence or distance. Given the presence of arbitrary finite sets in these problems, the methods used to attack these problems have primarily been combinatorial in nature. In recent years, however, many outstanding problems in these directions have been solved by algebraic means (and more specifically, using tools from algebraic geometry and/or algebraic topology), giving rise to an emerging set of techniques which is now known as the *polynomial method*. Broadly speaking, the strategy is to capture (or at least partition) the arbitrary sets of objects (viewed as points in some configuration space) in the zero set of a polynomial whose degree (or other measure of complexity) is under control; for instance, the degree may be bounded by some function of the number of objects. One then uses tools from algebraic geometry to understand the structure of this zero set, and thence to control the original sets of objects.

While various instances of the polynomial method have been known for decades (e.g. Stepanov's method, the combinatorial nullstellensatz, or Baker's theorem), the general theory of this method is still in the process of maturing; in particular, the limitations of the polynomial method are not well understood, and there is still considerable scope to apply deeper results from algebraic geometry or algebraic topology to strengthen the method further. In this survey we present several of the known applications of these

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Arithmetic And Combinatorics

**Jiri Herman, Radan Kucera, Jaromir
Simsa**

Arithmetic And Combinatorics:

Counting and Configurations Jiri Herman, Radan Kucera, Jaromir Simsa, 2013-03-14 This book can be seen as a continuation of *Equations and Inequalities Elementary Problems and Theorems in Algebra and Number Theory* by the same authors and published as the first volume in this book series However it can be independently read or used as a textbook in its own right This book is intended as a text for a problem solving course at the first or second year university level as a text for enrichment classes for talented high school students or for mathematics competition training It can also be used as a source of supplementary material for any course dealing with combinatorics graph theory number theory or geometry or for any of the discrete mathematics courses that are offered at most American and Canadian universities The underlying philosophy of this book is the same as that of *Equations and Inequalities* The following paragraphs are therefore taken from the preface of that book

Combinatorial Number Theory and Additive Group Theory Alfred Geroldinger, Imre Ruzsa, 2009-04-15 Additive combinatorics is a relatively recent term coined to comprehend the developments of the more classical additive number theory mainly focussed on problems related to the addition of integers Some classical problems like the Waring problem on the sum of k th powers or the Goldbach conjecture are genuine examples of the original questions addressed in the area One of the features of contemporary additive combinatorics is the interplay of a great variety of mathematical techniques including combinatorics harmonic analysis convex geometry graph theory probability theory algebraic geometry or ergodic theory This book gathers the contributions of many of the leading researchers in the area and is divided into three parts The two first parts correspond to the material of the main courses delivered Additive combinatorics and non unique factorizations by Alfred Geroldinger and Sumsets and structure by Imre Z Ruzsa The third part collects the notes of most of the seminars which accompanied the main courses and which cover a reasonably large part of the methods techniques and problems of contemporary additive combinatorics

Arithmetic and Combinatorics Gottfried Martin, 1985 This is the only work to provide a historical account of Kant's theory of arithmetic examining in detail the theories of both his predecessors and his successors Until his death Martin was the editor of *Kant Studien* from 1954 of the general Kant index from 1964 of the Leibniz index from 1968 and coeditor of *Leibnizstudien* from 1969 This background is used to its fullest as he strives to make clear the historical milieu in which Kant's mathematical contributions developed He uses Leibniz Wolff and others whose work was accomplished before Kant was born as well as Lambert Men delssohn and others roughly contemporary with Kant and when a point requires it he refers to Gauss Grassman Frege Russell and Hilbert In her translation Wubnig has approached the original author with an abiding respect She makes the translation flow in English while preserving as far as possible the flavor of the original She has added many bibliographical and biographical details to ease the following up of Martin's allusions and suggestions

Additive Combinatorics Terence Tao, Van H. Vu, 2006-09-14 Additive combinatorics is the theory of counting additive structures in sets This theory has seen exciting developments and

dramatic changes in direction in recent years thanks to its connections with areas such as number theory ergodic theory and graph theory This graduate level 2006 text will allow students and researchers easy entry into this fascinating field Here the authors bring together in a self contained and systematic manner the many different tools and ideas that are used in the modern theory presenting them in an accessible coherent and intuitively clear manner and providing immediate applications to problems in additive combinatorics The power of these tools is well demonstrated in the presentation of recent advances such as Szemer di s theorem on arithmetic progressions the Keakey conjecture and Erdos distance problems and the developing field of sum product estimates The text is supplemented by a large number of exercises and new results

Additive Combinatorics Andrew Granville,Melvyn Bernard Nathanson,Jozsef Solymosi, This book based in part on lectures delivered at the 2006 CRM Clay School on Additive Combinatorics brings together some of the top researchers in one of the hottest topics in analysis today This new subject brings together ideas from many different areas to prove some extraordinary results The book encompasses proceedings from the school articles on open questions in additive combinatorics and new research *Substitutions in Dynamics, Arithmetics and Combinatorics* N. Pytheas Fogg,2002-09-23 A certain category of infinite strings of letters on a finite alphabet is presented here chosen among the simplest possible one may build both because they are very deterministic and because they are built by simple rules a letter is replaced by a word a sequence is produced by iteration These substitutive sequences have a surprisingly rich structure The authors describe the concepts of quantity of natural interactions with combinatorics on words ergodic theory linear algebra spectral theory geometry of tilings theoretical computer science diophantine approximation transcendence graph theory This volume fulfils the need for a reference on the basic definitions and theorems as well as for a state of the art survey of the more difficult and unsolved problems **Additive Combinatorics** Andrew Granville,2007 One of the most active areas in mathematics today is the rapidly emerging new topic of additive combinatorics Building on Gowers use of the Freiman Ruzsa theorem in harmonic analysis in particular his proof of Szemer di s theorem Green and Tao famously proved that there are arbitrarily long arithmetic progressions of primes and Bourgain and his co authors have given non trivial estimates for hitherto untouchably short exponential sums There are further important consequences in group theory and in complexity theory and compelling questions in ergodic theory discrete geometry and man Mathematical Problems and Proofs Branislav Kisačanin,1998-10-31 Introduces the various fields of discrete mathematics to talented high school students and to undergraduates who would like to see illustrations of abstract mathematical concepts and learn a bit about their historic origin Also teaches how to read mathematical literature in general which is always with pencil and paper to hand Annotation copyrighted by Book News Inc Portland OR **Additive Combinatorics** Bela Bajnok,2018-04-27 Additive Combinatorics A Menu of Research Problems is the first book of its kind to provide readers with an opportunity to actively explore the relatively new field of additive combinatorics The author has written the book specifically for students of any background and

proficiency level from beginners to advanced researchers It features an extensive menu of research projects that are challenging and engaging at many different levels The questions are new and unsolved incrementally attainable and designed to be approachable with various methods The book is divided into five parts which are compared to a meal The first part is called Ingredients and includes relevant background information about number theory combinatorics and group theory The second part Appetizers introduces readers to the book s main subject through samples The third part Sides covers auxiliary functions that appear throughout different chapters The book s main course so to speak is Entrees it thoroughly investigates a large variety of questions in additive combinatorics by discussing what is already known about them and what remains unsolved These include maximum and minimum subset size spanning sets critical numbers and so on The final part is Pudding and features numerous proofs and results many of which have never been published Features The first book of its kind to explore the subject Students of any level can use the book as the basis for research projects The text moves gradually through five distinct parts which is suitable both for beginners without prerequisites and for more advanced students Includes extensive proofs of propositions and theorems Each of the introductory chapters contains numerous exercises to help readers

Combinatorics of Numbers Ihor Protasov,1997 *Introduction to Combinatorics* Martin J. Erickson,2013-06-13 Praise for the First Edition This excellent text should prove a useful accoutrement for any developing mathematics program it s short it s sweet it s beautifully written The Mathematical Intelligencer Erickson has prepared an exemplary work strongly recommended for inclusion in undergraduate level library collections Choice Featuring a modern approach *Introduction to Combinatorics* Second Edition illustrates the applicability of combinatorial methods and discusses topics that are not typically addressed in literature such as Alcuin s sequence Rook paths and Leech s lattice The book also presents fundamental results discusses interconnection and problem solving techniques and collects and disseminates open problems that raise questions and observations Many important combinatorial methods are revisited and repeated several times throughout the book in exercises examples theorems and proofs alike allowing readers to build confidence and reinforce their understanding of complex material In addition the author successfully guides readers step by step through three major achievements of combinatorics Van der Waerden s theorem on arithmetic progressions P lya s graph enumeration formula and Leech s 24 dimensional lattice Along with updated tables and references that reflect recent advances in various areas such as error correcting codes and combinatorial designs the Second Edition also features Many new exercises to help readers understand and apply combinatorial techniques and ideas A deeper investigative study of combinatorics through exercises requiring the use of computer programs Over fifty new examples ranging in level from routine to advanced that illustrate important combinatorial concepts Basic principles and theories in combinatorics as well as new and innovative results in the field *Introduction to Combinatorics* Second Edition is an ideal textbook for a one or two semester sequence in combinatorics graph theory and discrete mathematics at the upper undergraduate level The book is

also an excellent reference for anyone interested in the various applications of elementary combinatorics **102**

Combinatorial Problems Titu Andreescu, Zuming Feng, 2013-11-27 102 Combinatorial Problems consists of carefully selected problems that have been used in the training and testing of the USA International Mathematical Olympiad IMO team Key features Provides in depth enrichment in the important areas of combinatorics by reorganizing and enhancing problem solving tactics and strategies Topics include combinatorial arguments and identities generating functions graph theory recursive relations sums and products probability number theory polynomials theory of equations complex numbers in geometry algorithmic proofs combinatorial and advanced geometry functional equations and classical inequalities The book is systematically organized gradually building combinatorial skills and techniques and broadening the student's view of mathematics Aside from its practical use in training teachers and students engaged in mathematical competitions it is a source of enrichment that is bound to stimulate interest in a variety of mathematical areas that are tangential to combinatorics

Practice Combinatorics and Probability Cleo Borac, Silviu Borac, 2016-02-09 About Competitive Mathematics for Gifted Students This series provides practice materials and short theory reminders for students who aim to excel at problem solving Material is introduced in a structured manner each new concept is followed by a problem set that explores the content in detail Each book ends with a problem set that reviews both concepts presented in the current volume and related topics from previous volumes The series forms a learning continuum that explores strategies specific to competitive mathematics in depth and breadth Full solutions explain both reasoning and execution Often several solutions are contrasted The problem selection emphasizes comprehension critical thinking observation and avoiding repetitive and mechanical procedures Ready to participate in a math competition such as AMC 8 AMC 10 Math Kangaroo in USA Math Leagues USAMTS or AIME This series will open the doors to consistent performance About Level 3 This level of the series is designed for students who can solve linear equations are fluent with fractions and can factor into primes The problem sets are designed to strengthen specific areas where we know students have difficulty on AMC 8 and AMC 10 The level 3 books are a strong preparation for AMC 8 and a partial preparation for AMC 10 and AIME Level 3 consists of Word Problems volume 9 Arithmetic and Number Theory volume 10 Operations and Algebra volume 11 Geometry volume 12 and Combinatorics volume 13 On the contest list for this level MATHCOUNTS Math Kangaroo levels 5 6 and 7 8 MOEMS M Purple Comet AMC 8 AMC 10 Their complexity makes these problem sets useful for preparing the AIME in the long run About Volume 13 Combinatorics and Probability This workbook presents a variety of problems that explore the most basic discrete counting techniques permutations and combinations The topics included are competition specific Topics in Arithmetic Combinatorics B. Green, 2003 **Ergodic Theory and Dynamical Systems in their Interactions with Arithmetics and Combinatorics** Sébastien Ferenczi, Joanna Kułaga-Przymus, Mariusz Lemańczyk, 2018-06-15 This book concentrates on the modern theory of dynamical systems and its interactions with number theory and combinatorics The

greater part begins with a course in analytic number theory and focuses on its links with ergodic theory presenting an exhaustive account of recent research on Sarnak's conjecture on Möbius disjointness. Selected topics involving more traditional connections between number theory and dynamics are also presented including equidistribution, homogeneous dynamics and Lagrange and Markov spectra. In addition, some dynamical and number-theoretical aspects of aperiodic order, some algebraic systems and a recent development concerning tame systems are described.

Old and New Problems and Results in Combinatorial Number Theory Paul Erdős, Ronald L. Graham, 1980

Trilogy Of Numbers And Arithmetic - Book 1: History Of Numbers And Arithmetic: An Information Perspective Mark Burgin, 2022-04-22

The book is the first in the trilogy which will bring you to the fascinating world of numbers and operations with them. Numbers provide information about myriads of things. Together with operations, numbers constitute arithmetic, forming in basic intellectual instruments of theoretical and practical activity of people and offering powerful tools for representation, acquisition, transmission, processing, storage and management of information about the world. The history of numbers and arithmetic is the topic of a variety of books and at the same time it is extensively presented in many books on the history of mathematics. However, all of them at best bring the reader to the end of the 19th century without including the developments in these areas in the 20th century and later. Besides such books consider and describe only the most popular classes of numbers such as whole numbers or real numbers. At the same time, a diversity of new classes of numbers and arithmetic were introduced in the 20th century. This book looks into the chronicle of numbers and arithmetic from ancient times all the way to the 21st century. It also includes the developments in these areas in the 20th century and later. A unique aspect of this book is its information orientation of the exposition of the history of numbers and arithmetic.

Recursive Algebra, Analysis and Combinatorics, 1998-11-30

Recursive Algebra, Analysis and Combinatorics *An Introduction to Mathematical Reasoning* Peter J. Eccles, 1997-12-11

The purpose of this book is to introduce the basic ideas of mathematical proof to students embarking on university mathematics. The emphasis is on helping the reader in understanding and constructing proofs and writing clear mathematics. This is achieved by exploring set theory, combinatorics and number theory topics which include many fundamental ideas which are part of the tool kit of any mathematician. This material illustrates how familiar ideas can be formulated rigorously, provides examples demonstrating a wide range of basic methods of proof and includes some of the classic proofs. The book presents mathematics as a continually developing subject. Material meeting the needs of readers from a wide range of backgrounds is included. Over 250 problems include questions to interest and challenge the most able student as well as plenty of routine exercises to help familiarize the reader with the basic ideas.

Topics in Arithmetic Combinatorics in Function Fields Thái Hoàng Lê, 2010

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