

A Course in Convexity

Alexander Barvinok

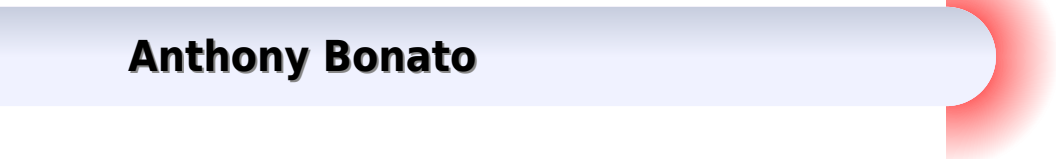
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By Alexander Barvinok A Course In Convexity

Anthony Bonato



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A Course in Convexity Alexander Barvinok, 2002-11-19 Convexity is a simple idea that manifests itself in a surprising variety of places This fertile field has an immensely rich structure and numerous applications Barvinok demonstrates that simplicity intuitive appeal and the universality of applications make teaching and learning convexity a gratifying experience The book will benefit both teacher and student It is easy to understand entertaining to the reader and includes many exercises that vary in degree of difficulty Overall the author demonstrates the power of a few simple unifying principles in a variety of pure and applied problems The prerequisites are minimal amounts of linear algebra analysis and elementary topology plus basic computational skills Portions of the book could be used by advanced undergraduates As a whole it is designed for graduate students interested in mathematical methods computer science electrical engineering and operations research The book will also be of interest to research mathematicians who will find some results that are recent some that are new and many known results that are discussed from a new perspective

A Course in Convexity Alexander Barvinok, 2025-05-06 Convexity is a simple idea that manifests itself in a surprising variety of places This fertile field has an immensely rich structure and numerous applications Barvinok demonstrates that simplicity intuitive appeal and the universality of applications make teaching and learning convexity a gratifying experience The book will benefit both teacher and student It is easy to understand entertaining to the reader and includes many exercises that vary in degree of difficulty Overall the author demonstrates the power of a few simple unifying principles in a variety of pure and applied problems The prerequisites are minimal amounts of linear algebra analysis and elementary topology plus basic computational skills Portions of the book could be used by advanced undergraduates As a whole it is designed for graduate students interested in mathematical methods computer science electrical engineering and operations research The book will also be of interest to research mathematicians who will find some results that are recent some that are new and many known results that are discussed from a new perspective

Convex Optimization & Euclidean Distance Geometry Jon Dattorro, 2005 The study of Euclidean distance matrices EDMs fundamentally asks what can be known geometrically given only distance information between points in Euclidean space Each point may represent simply location or abstractly any entity expressible as a vector in finite dimensional Euclidean space The answer to the question posed is that very much can be known about the points the mathematics of this combined study of geometry and optimization is rich and deep Throughout we cite beacons of historical accomplishment The application of EDMs has already proven invaluable in discerning biological molecular conformation The emerging practice of localization in wireless sensor networks the global positioning system GPS and distance based pattern recognition will certainly simplify and benefit from this theory We study the pervasive convex Euclidean bodies and their various representations In particular we make convex polyhedra cones and dual cones more visceral through illustration and we study the geometric relation of polyhedral cones to nonorthogonal bases biorthogonal expansion We explain

conversion between halfspace and vertex descriptions of convex cones we provide formulae for determining dual cones and we show how classic alternative systems of linear inequalities or linear matrix inequalities and optimality conditions can be explained by generalized inequalities in terms of convex cones and their duals The conic analogue to linear independence called conic independence is introduced as a new tool in the study of classical cone theory the logical next step in the progression linear affine conic Any convex optimization problem has geometric interpretation This is a powerful attraction the ability to visualize geometry of an optimization problem We provide tools to make visualization easier The concept of faces extreme points and extreme directions of convex Euclidean bodies is explained here crucial to understanding convex optimization The convex cone of positive semidefinite matrices in particular is studied in depth We mathematically interpret for example its inverse image under affine transformation and we explain how higher rank subsets of its boundary united with its interior are convex The Chapter on Geometry of convex functions observes analogies between convex sets and functions The set of all vector valued convex functions is a closed convex cone Included among the examples in this chapter we show how the real affine function relates to convex functions as the hyperplane relates to convex sets Here also pertinent results for multidimensional convex functions are presented that are largely ignored in the literature tricks and tips for determining their convexity and discerning their geometry particularly with regard to matrix calculus which remains largely unsystematized when compared with the traditional practice of ordinary calculus Consequently we collect some results of matrix differentiation in the appendices The Euclidean distance matrix EDM is studied its properties and relationship to both positive semidefinite and Gram matrices We relate the EDM to the four classical axioms of the Euclidean metric thereby observing the existence of an infinity of axioms of the Euclidean metric beyond the triangle inequality We proceed by deriving the fifth Euclidean axiom and then explain why furthering this endeavor is inefficient because the ensuing criteria while describing polyhedra grow linearly in complexity and number Some geometrical problems solvable via EDMs EDM problems posed as convex optimization and methods of solution are presented eg we generate a recognizable isotonic map of the United States using only comparative distance information no distance information only distance inequalities We offer a new proof of the classic Schoenberg criterion that determines whether a candidate matrix is an EDM Our proof relies on fundamental geometry assuming any EDM must correspond to a list of points contained in some polyhedron possibly at its vertices and vice versa It is not widely known that the Schoenberg criterion implies nonnegativity of the EDM entries proved here We characterize the eigenvalues of an EDM matrix and then devise a polyhedral cone required for determining membership of a candidate matrix in Cayley Menger form to the convex cone of Euclidean distance matrices EDM cone ie a candidate is an EDM if and only if its eigenspectrum belongs to a spectral cone for EDM N We will see spectral cones are not unique In the chapter EDM cone we explain the geometric relationship between the EDM cone two positive semidefinite cones and the elliptope We illustrate geometric requirements in particular for projection of a candidate matrix on a positive

semidefinite cone that establish its membership to the EDM cone The faces of the EDM cone are described but still open is the question whether all its faces are exposed as they are for the positive semidefinite cone The classic Schoenberg criterion relating EDM and positive semidefinite cones is revealed to be a discretized membership relation a generalized inequality a new Farkas like lemma between the EDM cone and its ordinary dual A matrix criterion for membership to the dual EDM cone is derived that is simpler than the Schoenberg criterion We derive a new concise expression for the EDM cone and its dual involving two subspaces and a positive semidefinite cone Semidefinite programming is reviewed with particular attention to optimality conditions of prototypical primal and dual conic programs their interplay and the perturbation method of rank reduction of optimal solutions extant but not well known We show how to solve a ubiquitous platonic combinatorial optimization problem from linear algebra the optimal Boolean solution x to $Ax \leq b$ via semidefinite program relaxation A three dimensional polyhedral analogue for the positive semidefinite cone of 3×3 symmetric matrices is introduced a tool for visualizing in 6 dimensions In EDM proximity we explore methods of solution to a few fundamental and prevalent Euclidean distance matrix proximity problems the problem of finding that Euclidean distance matrix closest to a given matrix in the Euclidean sense We pay particular attention to the problem when compounded with rank minimization We offer a new geometrical proof of a famous result discovered by Eckart Young in 1936 regarding Euclidean projection of a point on a subset of the positive semidefinite cone comprising all positive semidefinite matrices having rank not exceeding a prescribed limit ρ We explain how this problem is transformed to a convex optimization for any rank ρ

Fourier Analysis on Polytopes and the Geometry of Numbers Sinai Robins, 2024-04-24 This book offers a gentle introduction to the geometry of numbers from a modern Fourier analytic point of view One of the main themes is the transfer of geometric knowledge of a polytope to analytic knowledge of its Fourier transform The Fourier transform preserves all of the information of a polytope and turns its geometry into analysis The approach is unique and streamlines this emerging field by presenting new simple proofs of some basic results of the field In addition each chapter is fitted with many exercises some of which have solutions and hints in an appendix Thus an individual learner will have an easier time absorbing the material on their own or as part of a class Overall this book provides an introduction appropriate for an advanced undergraduate a beginning graduate student or researcher interested in exploring this important expanding field

Combinatorial Reciprocity Theorems Matthias Beck, Raman Sanyal, 2018-12-12 Combinatorial reciprocity is a very interesting phenomenon which can be described as follows A polynomial whose values at positive integers count combinatorial objects of some sort may give the number of combinatorial objects of a different sort when evaluated at negative integers and suitably normalized Such combinatorial reciprocity theorems occur in connections with graphs partially ordered sets polyhedra and more Using the combinatorial reciprocity theorems as a leitmotif this book unfolds central ideas and techniques in enumerative and geometric combinatorics Written in a friendly writing style this is an accessible graduate textbook with almost 300 exercises numerous

illustrations and pointers to the research literature Topics include concise introductions to partially ordered sets polyhedral geometry and rational generating functions followed by highly original chapters on subdivisions geometric realizations of partially ordered sets and hyperplane arrangements Computing the Continuous Discretely Matthias Beck, Sinai Robins, 2007-11-19 This textbook illuminates the field of discrete mathematics with examples theory and applications of the discrete volume of a polytope The authors have weaved a unifying thread through basic yet deep ideas in discrete geometry combinatorics and number theory We encounter here a friendly invitation to the field of counting integer points in polytopes and its various connections to elementary finite Fourier analysis generating functions the Frobenius coin exchange problem solid angles magic squares Dedekind sums computational geometry and more With 250 exercises and open problems the reader feels like an active participant **Integer Points in Polyhedra -- Geometry, Number Theory, Algebra, Optimization**

Alexander Barvinok, 2005 The AMS IMS SIAM Summer Research Conference on Integer Points in Polyhedra took place in Snowbird UT This proceedings volume contains original research and survey articles stemming from that event Topics covered include commutative algebra optimization discrete geometry statistics representation theory and symplectic geometry The book is suitable for researchers and graduate students interested in combinatorial aspects of the above fields

Alice and Bob Meet Banach Guillaume Aubrun, Stanisław J. Szarek, 2024-07-29 The quest to build a quantum computer is arguably one of the major scientific and technological challenges of the twenty first century and quantum information theory QIT provides the mathematical framework for that quest Over the last dozen or so years it has become clear that quantum information theory is closely linked to geometric functional analysis Banach space theory operator spaces high dimensional probability a field also known as asymptotic geometric analysis AGA In a nutshell asymptotic geometric analysis investigates quantitative properties of convex sets or other geometric structures and their approximate symmetries as the dimension becomes large This makes it especially relevant to quantum theory where systems consisting of just a few particles naturally lead to models whose dimension is in the thousands or even in the billions Alice and Bob Meet Banach is aimed at multiple audiences connected through their interest in the interface of QIT and AGA at quantum information researchers who want to learn AGA or apply its tools at mathematicians interested in learning QIT or at least the part of QIT that is relevant to functional analysis convex geometry random matrix theory and related areas and at beginning researchers in either field Moreover this user friendly book contains numerous tables and explicit estimates with reasonable constants when possible which make it a useful reference even for established mathematicians generally familiar with the subject A Course on the Web Graph Anthony Bonato, 2008 A Course on the Web Graph provides a comprehensive introduction to state of the art research on the applications of graph theory to real world networks such as the web graph It is the first mathematically rigorous textbook discussing both models of the web graph and algorithms for searching the web After introducing key tools required for the study of web graph mathematics an overview is given of the most widely studied models for the web graph A

discussion of popular web search algorithms e.g. PageRank is followed by additional topics such as applications of infinite graph theory to the web graph spectral properties of power law graphs domination in the web graph and the spread of viruses in networks The book is based on a graduate course taught at the AARMS 2006 Summer School at Dalhousie University As such it is self contained and includes over 100 exercises The reader of the book will gain a working knowledge of current research in graph theory and its modern applications In addition the reader will learn first hand about models of the web and the mathematics underlying modern search engines Publisher's description [An Introductory Course on Mathematical Game Theory](#) Julio González-Díaz, Ignacio García-Jurado, M. Gloria Fiestras-Janeiro, 2021-10-22 Game theory provides a mathematical setting for analyzing competition and cooperation in interactive situations The theory has been famously applied in economics but is relevant in many other sciences such as political science biology and more recently computer science This book presents an introductory and up to date course on game theory addressed to mathematicians and economists and to other scientists having a basic mathematical background The book is self contained providing a formal description of the classic game theoretic concepts together with rigorous proofs of the main results in the field The theory is illustrated through abundant examples applications and exercises The style is distinctively concise while offering motivations and interpretations of the theory to make the book accessible to a wide readership The basic concepts and results of game theory are given a formal treatment and the mathematical tools necessary to develop them are carefully presented Cooperative games are explained in detail with bargaining and TU games being treated as part of a general framework The authors stress the relation between game theory and operations research The book is suitable for a graduate or an advanced undergraduate course on game theory

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