

Radu Ioan Bot

# Conjugate Duality in Convex Optimization



Springer

# Conjugate Duality In Convex Optimization Lecture Notes In Economics And Mathematical Systems

**Ivan Singer**



## **Conjugate Duality In Convex Optimization Lecture Notes In Economics And Mathematical Systems:**

*Conjugate Duality in Convex Optimization* Radu Ioan Bot, 2009-12-24 The results presented in this book originate from the last decade research work of the author in the field of duality theory in convex optimization The reputation of duality in the optimization theory comes mainly from the major role that it plays in formulating necessary and sufficient optimality conditions and consequently in generating different algorithmic approaches for solving mathematical programming problems The investigations made in this work prove the importance of the duality theory beyond these aspects and emphasize its strong connections with different topics in convex analysis nonlinear analysis functional analysis and in the theory of monotone operators The first part of the book brings to the attention of the reader the perturbation approach as a fundamental tool for developing the so called conjugate duality theory The classical Lagrange and Fenchel duality approaches are particular instances of this general concept More than that the generalized interior point regularity conditions stated in the past for the two mentioned situations turn out to be particularizations of the ones given in this general setting In our investigations the perturbation approach represents the starting point for deriving new duality concepts for several classes of convex optimization problems Moreover via this approach generalized Moreau Rockafellar formulae are provided and in connection with them a new class of regularity conditions called closedness type conditions for both stable strong duality and strong duality is introduced By stable strong duality we understand the situation in which strong duality still holds whenever perturbing the objective function of the primal problem with a linear continuous functional

Conjugate Duality in Convex Optimization Radu Ioan-Bot, 2010-02-04 The results presented in this book originate from the last decade research work of the author in the field of duality theory in convex optimization The reputation of duality in the optimization theory comes mainly from the major role that it plays in formulating necessary and sufficient optimality conditions and consequently in generating different algorithmic approaches for solving mathematical programming problems The investigations made in this work prove the importance of the duality theory beyond these aspects and emphasize its strong connections with different topics in convex analysis nonlinear analysis functional analysis and in the theory of monotone operators The first part of the book brings to the attention of the reader the perturbation approach as a fundamental tool for developing the so called conjugate duality theory The classical Lagrange and Fenchel duality approaches are particular instances of this general concept More than that the generalized interior point regularity conditions stated in the past for the two mentioned situations turn out to be particularizations of the ones given in this general setting In our investigations the perturbation approach represents the starting point for deriving new duality concepts for several classes of convex optimization problems Moreover via this approach generalized Moreau Rockafellar formulae are provided and in connection with them a new class of regularity conditions called closedness type conditions for both stable strong duality and strong duality is introduced By stable strong duality we understand the situation in which strong duality still holds whenever perturbing the

objective function of the primal problem with a linear continuous functional

**Vector Optimization and Monotone Operators via Convex Duality** Sorin-Mihai Grad, 2014-09-03 This book investigates several duality approaches for vector optimization problems while also comparing them Special attention is paid to duality for linear vector optimization problems for which a vector dual that avoids the shortcomings of the classical ones is proposed Moreover the book addresses different efficiency concepts for vector optimization problems Among the problems that appear when the framework is generalized by considering set valued functions an increasing interest is generated by those involving monotone operators especially now that new methods for approaching them by means of convex analysis have been developed Following this path the book provides several results on different properties of sums of monotone operators

*Fundamentals of Convex Analysis and Optimization* Rafael Correa, Abderrahim Hantoute, Marco A. López, 2023-07-11 This book aims at an innovative approach within the framework of convex analysis and optimization based on an in depth study of the behavior and properties of the supremum of families of convex functions It presents an original and systematic treatment of convex analysis covering standard results and improved calculus rules in subdifferential analysis The tools supplied in the text allow a direct approach to the mathematical foundations of convex optimization in particular to optimality and duality theory Other applications in the book concern convexification processes in optimization non convex integration of the Fenchel subdifferential variational characterizations of convexity and the study of Chebychev sets At the same time the underlying geometrical meaning of all the involved concepts and operations is highlighted and duly emphasized A notable feature of the book is its unifying methodology as well as the novelty of providing an alternative or complementary view to the traditional one in which the discipline is presented to students and researchers This textbook can be used for courses on optimization convex and variational analysis addressed to graduate and post graduate students of mathematics and also students of economics and engineering It is also oriented to provide specific background for courses on optimal control data science operations research economics game theory etc The book represents a challenging and motivating development for those experts in functional analysis convex geometry and any kind of researchers who may be interested in applications of their work

Convex Optimization—Theory, Algorithms and Applications Balendu Bhooshan Upadhyay, Shashi Kant Mishra, Pierre Maréchal, 2025-04-25 This volume includes chapters on topics presented at the conference on Recent Trends in Convex Optimization Theory Algorithms and Applications RTCOTAA 2020 held at the Department of Mathematics Indian Institute of Technology Patna Bihar India from 29-31 October 2020 It discusses a comprehensive exploration of the realm of optimization encompassing both the theoretical underpinnings and the multifaceted real life implementations of the optimization theory It meticulously features essential optimization concepts such as convex analysis generalized convexity monotonicity etc elucidating their theoretical advancements and significance in the optimization sphere Multiobjective optimization is a pivotal topic which addresses the inherent difficulties faced in conflicting objectives The book delves into various theoretical

concepts and covers some practical algorithmic approaches to solve multiobjective optimization such as the line search and the enhanced non monotone quasi Newton algorithms It also deliberates on several other significant topics in optimization such as the perturbation approach for vector optimization and solution methods for set valued optimization Nonsmooth optimization is extensively covered with in depth discussions on various well known tools of nonsmooth analysis such as convexificators limiting subdifferentials tangential subdifferentials quasi differentials etc Notable optimization algorithms such as the interior point algorithm and Lemke s algorithm are dissected in detail offering insights into their applicability and effectiveness The book explores modern applications of optimization theory for instance optimized image encryption resource allocation target tracking problems deep learning entropy optimization etc Ranging from gradient based optimization algorithms to metaheuristic approaches such as particle swarm optimization the book navigates through the intersection of optimization theory and deep learning thereby unravelling new research perspectives in artificial intelligence machine learning and other fields of modern science Designed primarily for graduate students and researchers across a variety of disciplines such as mathematics operations research electrical and electronics engineering computer science robotics deep learning image processing and artificial intelligence this book serves as a comprehensive resource for someone interested in exploring the multifaceted domain of mathematical optimization and its myriad applications **Large-Scale Convex**

**Optimization** Ernest K. Ryu, Wotao Yin, 2022-12-01 Starting from where a first course in convex optimization leaves off this text presents a unified analysis of first order optimization methods including parallel distributed algorithms through the abstraction of monotone operators With the increased computational power and availability of big data over the past decade applied disciplines have demanded that larger and larger optimization problems be solved This text covers the first order convex optimization methods that are uniquely effective at solving these large scale optimization problems Readers will have the opportunity to construct and analyze many well known classical and modern algorithms using monotone operators and walk away with a solid understanding of the diverse optimization algorithms Graduate students and researchers in mathematical optimization operations research electrical engineering statistics and computer science will appreciate this concise introduction to the theory of convex optimization algorithms Optimization, Simulation, and Control Altannar

Chinchuluun, Panos M. Pardalos, Rentsen Enkhbat, Efstratios N. Pistikopoulos, 2012-11-28 Optimization simulation and control play an increasingly important role in science and industry Because of their numerous applications in various disciplines research in these areas is accelerating at a rapid pace This volume brings together the latest developments in these areas of research as well as presents applications of these results to a wide range of real world problems The book is composed of invited contributions by experts from around the world who work to develop and apply new optimization simulation and control techniques either at a theoretical level or in practice Some key topics presented include equilibrium problems multi objective optimization variational inequalities stochastic processes numerical analysis optimization in signal processing and

various other interdisciplinary applications This volume can serve as a useful resource for researchers practitioners and advanced graduate students of mathematics and engineering working in research areas where results in optimization simulation and control can be applied

Recent Developments in Optimization Theory and Nonlinear Analysis Yair Censor, Simeon Reich, 1997 This volume contains the refereed proceedings of the special session on Optimization and Nonlinear Analysis held at the Joint American Mathematical Society Israel Mathematical Union Meeting which took place at the Hebrew University of Jerusalem in May 1995 Most of the papers in this book originated from the lectures delivered at this special session In addition some participants who didn't present lectures and invited speakers who were unable to attend contributed their work The fields of optimization theory and nonlinear analysis continue to be very active This book presents not only the wide spectrum and diversity of the results but also their manifold connections to other areas such as differential equations functional analysis operator theory calculus of variations numerical analysis and mathematical programming In reading this book one encounters papers that deal for example with convex quasiconvex and generalized convex functions fixed and periodic points fractional linear transformations moduli of convexity monotone operators Morse lemmas Navier Stokes equations nonexpansive maps nonsmooth analysis numerical stability products of projections steepest descent the Leray Schauder degree the turnpike property and variational inequalities

Splitting Algorithms, Modern Operator Theory, and Applications Heinz H. Bauschke, Regina S. Burachik, D. Russell Luke, 2019-11-06 This book brings together research articles and state of the art surveys in broad areas of optimization and numerical analysis with particular emphasis on algorithms The discussion also focuses on advances in monotone operator theory and other topics from variational analysis and nonsmooth optimization especially as they pertain to algorithms and concrete implementable methods The theory of monotone operators is a central framework for understanding and analyzing splitting algorithms Topics discussed in the volume were presented at the interdisciplinary workshop titled Splitting Algorithms Modern Operator Theory and Applications held in Oaxaca Mexico in September 2017 Dedicated to Jonathan M Borwein one of the most versatile mathematicians in contemporary history this compilation brings theory together with applications in novel and insightful ways

Duality for Nonconvex Approximation and Optimization Ivan Singer, 2007-03-12 The theory of convex optimization has been constantly developing over the past 30 years Most recently many researchers have been studying more complicated classes of problems that still can be studied by means of convex analysis so called anticonvex and convex anticonvex optimization problems This manuscript contains an exhaustive presentation of the duality for these classes of problems and some of its generalization in the framework of abstract convexity This manuscript will be of great interest for experts in this and related fields

**Duality in Vector Optimization** Radu Ioan Bot, Sorin-Mihai Grad, Gert Wanka, 2009-08-12 This book presents fundamentals and comprehensive results regarding duality for scalar vector and set valued optimization problems in a general setting One chapter is exclusively consecrated to the scalar and vector Wolfe and Mond Weir duality schemes

**Fixed-Point Algorithms for Inverse Problems in Science and Engineering** Heinz H. Bauschke, Regina S.

Burachik, Patrick L. Combettes, Veit Elser, D. Russell Luke, Henry Wolkowicz, 2011-05-27 Fixed Point Algorithms for Inverse Problems in Science and Engineering presents some of the most recent work from top notch researchers studying projection and other first order fixed point algorithms in several areas of mathematics and the applied sciences The material presented provides a survey of the state of the art theory and practice in fixed point algorithms identifying emerging problems driven by applications and discussing new approaches for solving these problems This book incorporates diverse perspectives from broad ranging areas of research including variational analysis numerical linear algebra biotechnology materials science computational solid state physics and chemistry Topics presented include Theory of Fixed point algorithms convex analysis convex optimization subdifferential calculus nonsmooth analysis proximal point methods projection methods resolvent and related fixed point theoretic methods and monotone operator theory Numerical analysis of fixed point algorithms choice of step lengths of weights of blocks for block iterative and parallel methods and of relaxation parameters regularization of ill posed problems numerical comparison of various methods Areas of Applications engineering image and signal reconstruction and decompression problems computer tomography and radiation treatment planning convex feasibility problems astronomy adaptive optics crystallography molecular structure reconstruction computational chemistry molecular structure simulation and other areas Because of the variety of applications presented this book can easily serve as a basis for new and innovated research and collaboration

Unilateral Variational Analysis In Banach Spaces (In 2 Parts) Lionel Thibault, 2023-02-14 The monograph provides a detailed and comprehensive presentation of the rich and beautiful theory of unilateral variational analysis in infinite dimensions It is divided into two volumes named Part I and Part II Starting with the convergence of sets and the semilimits and semicontinuity of multimappings the first volume develops the theories of tangent cones of subdifferentials of convexity and duality in locally convex spaces of extended mean value inequalities in absence of differentiability of metric regularity of constrained optimization problems The second volume is devoted to special classes of non smooth functions and sets It expands the theory of subsmooth functions and sets of semiconvex functions and multimappings of primal lower regular functions of singularities of non smooth mappings of prox regular functions and sets in general spaces of differentiability of projection mapping and others for prox regular sets Both volumes I and II contain for each chapter extensive comments covering related developments and historical comments Connected area fields of the material are optimization optimal control variational inequalities differential inclusions mechanics economics The book is intended for PhD students researchers and practitioners using unilateral variational analysis tools

Convexity from the Geometric Point of View Vitor Balestro, Horst Martini, Ralph Teixeira, 2024-07-14 This text gives a comprehensive introduction to the common core of convex geometry Basic concepts and tools which are present in all branches of that field are presented with a highly didactic approach Mainly directed to graduate and advanced undergraduates the book is self contained in such

a way that it can be read by anyone who has standard undergraduate knowledge of analysis and of linear algebra. Additionally, it can be used as a single reference for a complete introduction to convex geometry and the content coverage is sufficiently broad that the reader may gain a glimpse of the entire breadth of the field and various subfields. The book is suitable as a primary text for courses in convex geometry and also in discrete geometry including polytopes. It is also appropriate for survey type courses in Banach space theory, convex analysis, differential geometry and applications of measure theory. Solutions to all exercises are available to instructors who adopt the text for coursework. Most chapters use the same structure with the first part presenting theory and the next containing a healthy range of exercises. Some of the exercises may even be considered as short introductions to ideas which are not covered in the theory portion. Each chapter has a notes section offering a rich narrative to accompany the theory, illuminating the development of ideas and providing overviews to the literature concerning the covered topics. In most cases, these notes bring the reader to the research front. The text includes many figures that illustrate concepts and some parts of the proofs, enabling the reader to have a better understanding of the geometric meaning of the ideas. An appendix containing basic and geometric measure theory collects useful information for convex geometers. Mathematics Without Boundaries Panos M. Pardalos, Themistocles M.

Rassias, 2014-09-16 This volume consists of chapters written by eminent scientists and engineers from the international community and present significant advances in several theories, methods and applications of an interdisciplinary research. These contributions focus on both old and recent developments of Global Optimization Theory, Convex Analysis, Calculus of Variations, Discrete Mathematics and Geometry as well as several applications to a large variety of concrete problems including applications of computers to the study of smoothness and analyticity of functions, applications to epidemiological diffusion networks, mathematical models of elastic and piezoelectric fields, optimal algorithms, stability of neutral type vector functional differential equations, sampling and rational interpolation for non band limited signals, recurrent neural network for convex optimization problems and experimental design. The book also contains some review works which could prove particularly useful for a broader audience of readers in Mathematical and Engineering subjects and especially to graduate students who search for the latest information. Operations Research Proceedings 2013 Dennis Huisman, Ilse

Louwerse, Albert P.M. Wagelmans, 2014-07-10 This book contains a selection of refereed papers presented at the International Conference on Operations Research OR 2013 which took place at Erasmus University Rotterdam September 3-6 2013. The conference was jointly organized by the German and the Dutch OR Society. More than 800 scientists and students from over 50 countries attended OR 2013 and presented more than 600 papers in parallel topical streams as well as special award sessions. The theme of the conference and its proceedings is Impact on People, Business and Society. Parametric Optimization and Related Topics Jürgen Guddat, Hubertus Th. Jongen, Bernd Kummer, František Nožička, 1987-12-31 No detailed description available for Parametric Optimization and Related Topics. Advances in Mathematical Economics



Volume 7 Shigeo Kusuoka, Akira Yamazaki, 2006-06-22 A lot of economic problems can be formulated as constrained optimizations and equilibration of their solutions Various mathematical theories have been supplying economists with indispensable machineries for these problems arising in economic theory Conversely mathematicians have been stimulated by various mathematical difficulties raised by economic theories The series is designed to bring together those mathematicians who are seriously interested in getting new challenging stimuli from economic theories with those economists who are seeking effective mathematical tools for their research The editorial board of this series comprises the following prominent economists and mathematicians Managing Editors S Kusuoka Univ Tokyo T Maruyama Keio Univ Editors R Anderson U C Berkeley C Castaing Univ Montpellier F H Clarke Univ Lyon I G Debreu U C Berkeley E Dierker Univ Vienna D Duffie Stanford Univ L C Evans U C Berkeley T Fujimoto Okayama Univ J M Grandmont CREST CNRS N Hirano Yokohama National Univ L Hurwicz Univ of Minnesota T Ichiishi Ohio State Univ A Ioffe Israel Institute of Technology S Iwamoto Kyushu Univ K Kamiya Univ Tokyo K Kawamata Keio Univ N Kikuchi Keio Univ H Matano Univ Tokyo K Nishimura Kyoto Univ M K Richter Univ Minnesota Y Takahashi Kyoto Univ M Valadier Univ Montpellier II A Yamaguti Kyoto Univ Ryukoku Univ M Yano Keio Univ

*Optimization and Operations Research* W. Oettli, K. Ritter, 2012-12-06 The variable metric algorithm is widely recognised as one of the most efficient ways of solving the following problem Locate  $x$  a local minimum point  $n$  1 of  $f$   $x \in E \subset \mathbb{R}^n$  Considerable attention has been given to the study of the convergence properties of this algorithm especially for the case where analytic expressions are available for the derivatives  $g$  of  $f$  at  $x$  In particular we shall mention the results of Wolfe 1969 and Powell 1972 1975 Wolfe established general conditions under which a descent algorithm will converge to a stationary point and Powell showed that two particular very efficient algorithms that cannot be shown to satisfy Wolfe's conditions do in fact converge to the minimum of convex functions under certain conditions These results will be stated more completely in Section 2 In most practical problems analytic expressions for the gradient vector  $g$  Equ 2 are not available and numerical derivatives are subject to truncation error In Section 3 we shall consider the effects of these errors on Wolfe's convergent properties and will discuss possible modifications of the algorithms to make them reliable in these circumstances The effects of rounding error are considered in Section 4 whilst in Section 5 these thoughts are extended to include the case of on line function minimisation where each function evaluation is subject to random noise

Generalized Convexity and Generalized Monotonicity Nicolas Hadjisavvas, Juan E. Martinez-Legaz, Jean-Paul Penot, 2012-12-06 Various generalizations of convex functions have been introduced in areas such as mathematical programming economics management science engineering stochastics and applied sciences for example Such functions preserve one or more properties of convex functions and give rise to models which are more adaptable to real world situations than convex models Similarly generalizations of monotone maps have been studied recently A growing literature of this interdisciplinary field has appeared and a large number of international meetings are entirely devoted or include clusters on generalized convexity and

generalized monotonicity The present book contains a selection of refereed papers presented at the 6th International Symposium on Generalized Convexity Monotonicity and aims to review the latest developments in the field

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