Convex Analysis And Minimization Algorithms Part 2 Advanced Theory And Bundle Methods 1st Edition

This book treats various concepts of generalized derivatives and subdifferentials in normed spaces, their geometric counterparts and their application to optimization problems. It starts with the subdifferential of convex analysis, passes to corresponding concepts for locally Lipschitz continuous functions and then presents subdifferentials for general lower semicontinuous functions. All basic tools are presented where they are needed: this concerns separation theorems, variational and extremal principles as well as relevant parts of multifunction theory. Each chapter ends with bibliographic notes and exercises.

This book is an abridged version of the two volumes "Convex Analysis and Minimization Algorithms I and II" (Grundlehren der mathematischen Wissenschaften Vol. 305 and 306). It presents an introduction to the basic concepts in convex analysis and a study of convex minimization problems (with an emphasis on numerical algorithms). The "backbone" of bot volumes was extracted, some material deleted which was deemed too advanced for an introduction, or too closely attached to numerical algorithms. Some exercises were included and finally the index has been considerably enriched, making it an excellent choice for the purpose of learning and teaching.

This monograph develops a framework for modeling and solving utility maximization problems in nonconvex wireless systems. The first part develops a model for utility optimization in wireless systems. The model is general enough to encompass a wide array of system configurations and performance objectives. Based on the general model, a set of methods for solving utility maximization problems is developed in the second part of the book. The development is based on a careful examination of the properties that are required for the application of each method. This part focuses on problems whose initial formulation does not allow for a solution by standard methods and discusses alternative approaches. The last part presents two case studies to demonstrate the application of the proposed framework. In both cases, utility maximization in multi-antenna broadcast channels is investigated.

Most global optimization literature focuses on theory. This book, however, contains descriptions of new implementations of general-purpose or problem-specific global optimization algorithms. It discusses existing software packages from which the entire community can learn. The contributors are experts in the discipline of actually getting global optimization to work, and the book provides a source of ideas for people needing to implement global optimization software.

This reference text, now in its second edition, offers a modern unifying presentation of three basic areas of nonlinear analysis: convex analysis, monotone operator theory, and the fixed point theory of nonexpansive operators. Taking a unique comprehensive approach, the theory is developed from the ground up, with the rich connections and interactions between the areas as the central focus, and it is illustrated by a large number of examples. The Hilbert space setting of the material offers a wide range of applications while avoiding the technical difficulties of general Banach spaces. The authors have also drawn upon recent advances and modern tools to simplify the proofs of key results making the book more accessible to a broader range of scholars and users. Combining a strong emphasis on applications with exceptionally lucid writing and an abundance of exercises, this text is of great value to a large audience including pure and applied mathematicians as well as researchers in engineering, data science, machine learning, physics, decision sciences, economics, and inverse problems. The second edition of Convex Analysis and Monotone Operator Theory in Hilbert Spaces greatly expands on the first edition, containing over 140 pages of new material, over 270 new results, and more than 100 new exercises. It features a new chapter on proximity operators including two sections on proximity operators of matrix functions, in addition to several new sections distributed throughout the original chapters. Many existing results have been improved, and the list of references has been updated. Heinz H. Bauschke is a Full Professor of Mathematics at the Kelowna campus of the University of British Columbia, Canada. Patrick L. Combettes, IEEE Fellow, was on the faculty of the City University of New York and of Université Pierre et Marie Curie – Paris 6 before joining North Carolina State University as a Distinguished Professor of Mathematics in 2016.

From the reviews: "The account is quite detailed and is written in a manner that will appeal to analysts and numerical practitioners alike...they contain everything from rigorous proofs to tables of numerical calculations.... one of the strong features of these books...that they are designed not for the expert, but for those who whish to learn the subject matter starting from little or no background...there are numerous examples, and counter-examples, to back up the theory...To my knowledge, no other authors have given such a clear geometric account of convex analysis." "This innovative text is well written, copiously illustrated, and accessible to a wide audience"

Optimization is a rich and thriving mathematical discipline, and the underlying theory of current computational optimization techniques grows ever more sophisticated. This book aims to provide a concise, accessible account of convex analysis and its applications and extensions, for a broad audience. Each section concludes with an often extensive set of optional exercises. This new edition adds material on semismooth optimization, as well as several new proofs.

This tutorial contains written versions of seven lectures on Computational Combinatorial Optimization given by leading members of the optimization community. The lectures introduce modern combinatorial optimization techniques, with an emphasis on branch and cut algorithms and Lagrangian relaxation approaches. Polyhedral combinatorics as the mathematical backbone of successful algorithms are covered from many perspectives, in particular, polyhedral projection and lifting techniques and the importance of modeling are extensively discussed. Applications to prominent combinatorial optimization problems, e.g., in production and transport planning, are treated in many places; in particular, the book contains a state-of-the-art account of the most successful techniques for solving the traveling salesman problem to optimality.

This book contains three well-written research tutorials that inform the graduate reader about the forefront of current research in multi-agent optimization. These tutorials cover topics that have not yet found their way in standard books and offer the reader the unique opportunity to be guided by major researchers in the respective fields. Multi-agent optimization, lying at the intersection of classical optimization, game theory, and variational inequality theory, is at the forefront of modern optimization and has recently undergone a dramatic development. It seems timely to provide an overview that describes in detail ongoing research and important trends. This book concentrates on Distributed Optimization over Networks; Differential Variational Inequalities; and Advanced Decomposition Algorithms for Multi-agent Systems. This book will appeal to both mathematicians and mathematically oriented engineers and will be the source of inspiration for PhD students and researchers.

Since I started working in the area of nonlinear programming and, later on, variational inequality problems, I have frequently been surprised to find that many algorithms, however scattered in numerous journals, monographs and books, and described rather differently, are closely related to each other. This book is meant to help the reader understand and relate algorithms to each other in some intuitive fashion, and represents, in this respect, a consolidation of the field. The framework of algorithms presented in this book is called Cost Approxi mation. (The preface of the Ph.D. thesis [Pat93d] explains the background to the work that lead to the thesis, and ultimately to this book.) It describes, for a given formulation of a variational inequality or nonlinear programming problem, an algorithm by means of approximating mappings and problems, a principle for the update of the iteration points, and a merit function which guides and monitors the convergence of the algorithm. One purpose of this book is to offer this framework as an intuitively appeal ing tool for describing an algorithm. One of the advantages of the framework, or any reasonable framework for that matter, is that two algorithms may be easily related and compared through its use. This framework is particular in that it covers a vast number of methods, while still being fairly detailed; the level of abstraction is in fact the same as that of the original problem statement.

The aim of this book is to provide a concise but complete introduction to the main mathematical tools of nonlinear functional analysis, which are also used in the study of concrete problems in economics, engineering, and physics. This volume gathers the mathematical background needed in order to conduct research or to deal with theoretical problems and applications using the tools of nonlinear functional analysis.

Oleg Wilfer presents a new conjugate duality concept for geometric and cone constrained optimization problems whose objective functions are a composition of finitely many functions. As an application, the author derives results for single minmax location problems formulated by means of extended perturbed minimal time functions as well as for multi-facility minmax location problems defined by gauges. In addition, he provides formulae of projections onto the epigraphs of gauges to solve these kinds of location problems numerically by using parallel splitting algorithms. Numerical comparisons of recent methods show the excellent performance of the proposed solving technique. ?About the Author: Dr. Oleg Wilfer received his PhD at the Faculty of Mathematics of Chemnitz University of Technology, Germany. He is currently working as a development engineer in the automotive industry.

The book is devoted to the study of approximate solutions of optimization problems in the presence of computational errors. It contains a number of results on the convergence behavior of algorithms in a Hilbert space, which are known as important tools for solving optimization problems. The research presented in the book is the continuation and the further development of the author's (c) 2016 book Numerical Optimization with Computational Errors, Springer 2016. Both books study the algorithms taking into account computational errors which are always present in practice. The main goal is, for a known computational error, to find out what an approximate solution can be obtained and how many iterates one needs for this. The main difference between this new book and the 2016 book is that in this present book the discussion takes into consideration the fact that for every algorithm, its iteration consists of several steps and that computational errors for different steps are generally, different. This fact, which was not taken into account in the previous book, is indeed important in practice. For example, the subgradient projection algorithm consists of two steps. The first step is a calculation of a subgradient of the objective function while in the second one we calculate a projection on the feasible set. In each of these two steps there is a computational error and these two computational errors are different in general. It may happen that the feasible set is simple and the objective function is complicated. As a result, the computational error, made when one calculates the projection, is essentially smaller than the computational error of the calculation of the subgradient. Clearly, an opposite case is possible too. Another feature of this book is a study of a number of important algorithms which appeared recently in the literature and which are not discussed in the previous book. This monograph contains 12 chapters. Chapter 1 is an introduction. In Chapter 2 we study the subgradient projection algorithm for minimization of convex and nonsmooth functions. We generalize the results of [NOCE] and establish results which has no prototype in [NOCE]. In Chapter 3 we analyze the mirror descent algorithm for minimization of convex and nonsmooth functions, under the presence of computational errors. For this algorithm each iteration consists of two steps. The first step is a calculation of a subgradient of the objective function while in the second one we solve an auxiliary minimization problem on the set of feasible points. In each of these two steps there is a computational error. We generalize the results of [NOCE] and establish results which has no prototype in [NOCE]. In Chapter 4 we analyze the projected gradient algorithm with a smooth objective function under the presence of computational errors. In Chapter 5 we consider an algorithm, which is an extension of the projection gradient algorithm used for solving linear inverse problems arising in signal/image processing. In Chapter 6 we study continuous subgradient method and continuous subgradient projection algorithm for minimization of convex nonsmooth functions and for computing the saddle points of convex-concave functions, under the presence of computational errors. All the results of this chapter has no prototype in [NOCE]. In Chapters 7-12 we analyze several algorithms under the presence of computational errors which were not considered in [NOCE]. Again, each step of an iteration has a computational errors and we take into account that these errors are, in general, different. An optimization problems with a composite objective function is studied in Chapter 7. A zero-sum game with two-players is considered in Chapter 8. A predicted decrease approximation-based method is used in Chapter

9 for constrained convex optimization. Chapter 10 is devoted to minimization of quasiconvex functions. Minimization of sharp weakly convex functions is discussed in Chapter 11. Chapter 12 is devoted to a generalized projected subgradient method for minimization of a convex function over a set which is not necessarily convex. The book is of interest for researchers and engineers working in optimization. It also can be useful in preparation courses for graduate students. The main feature of the book which appeals specifically to this audience is the study of the influence of computational errors for several important optimization algorithms. The book is of interest for experts in applications of optimization to engineering and economics.

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" 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.

This book provides a comprehensive, modern introduction to convex optimization, a field that is becoming increasingly important in applied mathematics, economics and finance, engineering, and computer science, notably in data science and machine learning. Written by a leading expert in the field, this book includes recent advances in the algorithmic theory of convex optimization, naturally complementing the existing literature. It contains a unified and rigorous presentation of the acceleration techniques for minimization schemes of first- and second-order. It provides readers with a full treatment of the smoothing technique, which has tremendously extended the abilities of gradient-type methods. Several powerful approaches in structural optimization, including optimization in relative scale and polynomial-time interior-point methods, are also discussed in detail. Researchers in theoretical optimization as well as professionals working on optimization problems will find this book very useful. It presents many successful examples of how to develop very fast specialized minimization algorithms. Based on the author's lectures, it can naturally serve as the basis for introductory and advanced courses in convex optimization for students in engineering, economics, computer science and mathematics.

This focused monograph presents a study of subgradient algorithms for constrained minimization problems in a Hilbert space. The book is of interest for experts in applications of optimization to engineering and economics. The goal is to obtain a good approximate solution of the problem in the presence of computational errors. The discussion takes into consideration the fact that for every algorithm its iteration consists of several steps and that computational errors for different steps are different, in general. The book is especially useful for the reader because it contains solutions to a number of difficult and interesting problems in the numerical optimization. The subgradient projection algorithm is one of the most important tools in optimization theory and its applications. An optimization problem is described by an objective function and a set of feasible points. For this algorithm each iteration consists of two steps. The first step requires a calculation of a subgradient of the objective function; the second requires a calculation of a projection on the feasible set. The computational errors in each of these two steps are different. This book shows that the algorithm discussed, generates a good approximate solution, if all the computational errors are bounded from above by a small positive constant. Moreover, if computational errors for the two steps of the algorithm are known, one discovers an approximate solution and how many iterations one needs for this. In addition to their mathematical interest, the generalizations considered in this book have a significant practical meaning.

It has widely been recognized that submodular functions play essential roles in efficiently solvable combinatorial optimization problems. Since the publication of the 1st edition of this book fifteen years ago, submodular functions have been showing further increasing importance in optimization, combinatorics, discrete mathematics, algorithmic computer science, and algorithmic economics, and there have been made remarkable developments of theory and algorithms in submodular functions. The 2nd edition of the book supplements the 1st edition with a lot of remarks and with new two chapters: "Submodular Function Minimization" and "Discrete Convex Analysis." The present 2nd edition is still a unique book on submodular functions, which is essential to students and researchers interested in combinatorial optimization, discrete mathematics, and discrete algorithms in the fields of mathematics, operations research, computer science, and economics. Key features: - Self-contained exposition of the theory of submodular functions. - Selected up-to-date materials substantial to future developments. - Polyhedral description of Discrete Convex Analysis. - Full description of submodular function minimization algorithms. - Effective insertion of figures. - Useful in applied mathematics, operations research, computer science, and economics. - Self-contained exposition of the theory of submodular functions. - Selected up-to-date materials substantial to future developments. - Polyhedral description of Discrete Convex Analysis. - Full description of submodular function minimization algorithms. - Effective insertion of figures. - Useful in

applied mathematics, operations research, computer science, and economics.
This book starts with illustrations of the ubiquitous character of optimization, and describes numerical algorithms in a tutorial way. It covers fundamental algorithms as well as more specialized and advanced topics for unconstrained and constrained problems. This new edition of Numerical Optimization contains computational exercises in the form of case studies which help understanding optimization methods beyond their theoretical description when coming to actual implementation.
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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.
Since nonsmooth optimization problems arise in a diverse range of real-world applications, the potential impact of efficient methods for solving such problems is undeniable. Even solving difficult smooth problems sometimes requires the use of nonsmooth optimization methods, in order to either reduce the problem's scale or simplify its structure. Accordingly, the field of nonsmooth optimization is an important area of mathematical programming that is based on by now classical concepts of variational analysis and generalized derivatives, and has developed a rich and sophisticated set of mathematical tools at the intersection of theory and practice. This volume of ISNM is an outcome of the workshop "Nonsmooth Optimization and its Applications," which was held from May 15 to 19, 2017 at the Hausdorff Center for Mathematics, University of Bonn. The six research articles gathered here focus on recent results that highlight different aspects of nonsmooth and variational analysis, optimization methods, their convergence theory and applications.
This book constitutes the thoroughly refereed post-proceedings of the First International Workshop on Global Constraints Optimization and Costraint Satisfaction, COCOS 2002, held in Valbonne-Sophia Antipolis, France in October 2002. The 15 revised full papers presented together with 2 invited papers were carefully selected during two rounds of reviewing and improvement. The papers address current issues in global optimization, mathematical programming, and constraint programming; they are grouped in topical sections on optimization, constraint satisfaction, and benchmarking.
This book contains the results in numerical analysis and optimization presented at the ECCOMAS thematic conference "Computational Analysis and Optimization" (CAO 2011) held in Jyväskylä, Finland, June 9–11, 2011. Both the conference and this volume are dedicated to Professor Pekka Neittaanmäki on the occasion of his sixtieth birthday. It consists of five parts that are closely related to his scientific activities and interests: Numerical Methods for Nonlinear

Problems; Reliable Methods for Computer Simulation; Analysis of Noised and Uncertain Data; Optimization Methods; Mathematical Models Generated by Modern Technological Problems. The book also includes a short biography of Professor Neittaanmäki.

It was in the middle of the 1980s, when the seminal paper by Kar markar opened a new epoch in nonlinear optimization. The importance of this paper, containing a new polynomial-time algorithm for linear op timization problems, was not only in its complexity bound. At that time, the most surprising feature of this algorithm was that the theoretical pre diction of its high efficiency was supported by excellent computational results. This unusual fact dramatically changed the style and direc tions of the research in nonlinear optimization. Thereafter it became more and more common that the new methods were provided with a complexity analysis, which was considered a better justification of their efficiency than computational experiments. In a new rapidly develop ing field, which got the name "polynomial-time interior-point methods", such a justification was obligatory. Afteralmost fifteen years of intensive research, the main results of this development started to appear in monographs [12, 14, 16, 17, 18, 19]. Approximately at that time the author was asked to prepare a new course on nonlinear optimization for graduate students. The idea was to create a course which would reflect the new developments in the field. Actually, this was a major challenge. At the time only the theory of interior-point methods for linear optimization was polished enough to be explained to students. The general theory of self-concordant functions had appeared in print only once in the form of research monograph [12].

Special tools are required for examining and solving optimization problems. The main tools in the study of local optimization are classical calculus and its modern generalizions which form nonsmooth analysis. The gradient and various kinds of generalized derivatives allow us to ac complish a local approximation of a given function in a neighbourhood of a given point. This kind of approximation is very useful in the study of local extrema. However, local approximation alone cannot help to solve many problems of global optimization, so there is a clear need to develop special global tools for solving these problems. The simplest and most well-known area of global and simultaneously local optimization is convex programming. The fundamental tool in the study of convex optimization problems is the subgradient, which actu ally plays both a local and global role. First, a subgradient of a convex function f at a point x carries out a local approximation of f in a neigh bourhood of x. Second, the subgradient permits the construction of an affine function, which does not exceed f over the entire space and coincides with f at x. This affine function h is called a support func tion. Since f(y) ~ h(y) for ally, the second role is global. In contrast to a local approximation, the function h will be called a global affine support.

An insightful, concise, and rigorous treatment of the basic theory of convex sets and functions in finite dimensions, and the analytical/geometrical foundations of convex optimization and duality theory. Convexity theory is first developed in a simple accessible manner, using easily visualized proofs. Then the focus shifts to a transparent geometrical line of analysis to develop the fundamental duality between descriptions of convex functions in terms of points, and in terms of hyperplanes. Finally, convexity theory and abstract duality are applied to problems of constrained optimization, Fenchel and conic duality, and game theory to develop the sharpest possible duality results within a highly visual geometric framework. This on-line version of the book, includes an extensive set of theoretical problems with detailed high-quality solutions, which significantly extend the range and value of the book. The book may be used as a text for a theoretical convex optimization course; the author has taught several variants of such a course at MIT and elsewhere over the last ten years. It may also be used as a supplementary source for nonlinear programming classes, and as a theoretical foundation for classes focused on convex optimization models (rather than theory). It is an excellent supplement to several of our books: Convex Optimization Algorithms (Athena Scientific, 2015), Nonlinear Programming (Athena Scientific, 2017), Network Optimization(Athena Scientific, 1998), Introduction to Linear Optimization (Athena Scientific, 1997), and Network Flows and Monotropic Optimization (Athena Scientific, 1998).

Discrete Convex Analysis is a novel paradigm for discrete optimization that combines the ideas in continuous optimization (convex analysis) and combinatorial optimization (matroid/submodular function theory) to establish a unified theoretical framework for nonlinear discrete optimization. The study of this theory is expanding with the development of efficient algorithms and applications to a number of diverse disciplines like matrix theory, operations research, and economics. This self-contained book is designed to provide a novel insight into optimization on discrete structures and should reveal unexpected links among different disciplines. It is the first and only English-language monograph on the theory and applications of discrete convex analysis. Discrete Convex Analysis provides the information that professionals in optimization will need to "catch up" with this new theoretical development. It also presents an unexpected connection between matroid theory and mathematical economics and expounds a deeper connection between matrices and matroids than most standard textbooks.

The aim of this work is to present in a unified approach a series of results concerning totally convex functions on Banach spaces and their applications to building iterative algorithms for computing common fixed points of mea surable families of operators and optimization methods in infinite dimen sional settings. The notion of totally convex function was first studied by Butnariu, Censor and Reich [31] in the context of the space IRR because of its usefulness for establishing convergence of a Bregman projection method for finding common points of infinite families of closed convex sets. In this finite dimensional environment total convexity hardly differs from strict convexity. In fact, a function with closed domain in a finite dimensional Banach space is totally convex if and only if it is strictly convex. The relevancy of total convexity as a strengthened form of strict convexity becomes apparent when the Banach space on which the function is defined is infinite dimensional. In this case, total convexity is a property stronger than strict convexity but weaker than locally uniform convexity (see Section 1.3 below). The study of totally convex functions in infinite dimensional Banach spaces was started in [33] where it was shown that they are useful tools for extrapolating properties commonly known to belong to operators satisfying demanding contractivity requirements to classes of operators which are not even mildly nonexpansive.

There has been much recent progress in global optimization algo rithms for nonconvex continuous and discrete problems from both a theoretical and a practical perspective. Convex analysis plays a fun damental role in the analysis and development of global optimization algorithms. This is due essentially to the fact that virtually all noncon vex optimization problems can be described using differences of convex functions and differences of convex sets. A conference on Convex Analysis and Global Optimization was held during June 5 -9, 2000 at Pythagorion, Samos, Greece. The conference was honoring the memory of C. Caratheodory (1873-1950) and was en dorsed by the Mathematical Programming Society (MPS) and by the Society for Industrial and Applied Mathematics (SIAM) Activity Group in Optimization. The conference was sponsored by the European Union (through the EPEAEK program), the Department of Mathematics of the Aegean University and the Center for Applied Optimization of the University of Florida, by the General Secretariat of Research and Tech nology of Greece, by the Ministry of Education of Greece, and several local Greek government agencies and companies. This volume contains a selective collection of refereed papers based on invited and contribut ing talks presented at this conference. The two themes of convexity and global optimization pervade this book. The conference provided a forum for researchers working on different aspects of convexity and global opti mization to present their recent discoveries, and to interact with people working on complementary aspects of mathematical programming.

Convex Analysis may be considered as a refinement of standard calculus, with equalities and approximations replaced by inequalities. As such, it can easily be integrated into a graduate study curriculum. Minimization algorithms, more specifically those adapted to non-differentiable functions, provide an immediate application of convex analysis to various fields related to optimization and operations research. These two topics making up the title of the book, reflect the two origins of the authors, who belong respectively to the academic world and to that of applications. Part I can be used as an introductory textbook (as a basis for courses, or for self-study); Part II continues this at a higher technical level and is addressed more to specialists, collecting results that so far have not appeared in books.