Projected Dynamical Systems and Variational Inequalities with Applications

An up-to-date and unified treatment of bifurcation theory for variational inequalities in reflexive spaces and the use of the theory in a variety of applications, such as: obstacle problems from elasticity theory, unilateral problems; torsion problems; equations from fluid mechanics and quasilinear elliptic partial differential equations. The tools employed are those of modern nonlinear analysis. Accessible to graduate students and researchers who work in nonlinear analysis, nonlinear partial differential equations, and additional research disciplines that use nonlinear mathematics. This research monograph represents an outcome of the cross-fertilization between nonlinear functional analysis and mathematical modelling, and demonstrates its application to solid and contact mechanics. Based on authors' original results, it introduces a general fixed point principle and its application to various nonlinear problems in analysis and mechanics. The classes of history-dependent operators and almost history-dependent operators are exposed in a large generality. A systematic and unified presentation contains a carefully-selected collection of new results on variational-hemivariational inequalities with or without unilateral constraints. A wide spectrum of static, quasistatic, dynamic contact problems for elastic, viscoelastic and viscoplastic materials illustrates the applicability of these theoretical results. Written for mathematicians, applied mathematicians, engineers and scientists, it is also a valuable tool for graduate students and researchers in nonlinear analysis, mathematical modelling, mechanics of solids, and contact mechanics.

Numerical Analysis of Variational Inequalities

An up-to-date and unified treatment of bifurcation theory for variational inequalities in reflexive spaces and the use of the theory in a variety of applications, such as: obstacle problems from elasticity theory, unilateral problems; torsion problems; equations from fluid mechanics and quasilinear elliptic partial differential equations. The tools employed are those of modern nonlinear analysis. Accessible to graduate students and researchers who work in nonlinear analysis, nonlinear partial differential equations, and additional research disciplines that use nonlinear mathematics. These notes are the contents of a one semester graduate course which taught at Brown University during the academic year 1981-1982. They are mainly concerned with...
regularity theory for obstacle problems and with the dam problem, which, in the
rectangular case, is one of the most in teresting applications of Variational Inequalities
with an obstacle: Very little background is needed to read these notes. The main re sults
of functional analysis which are used here are recalled in the text. The goal of the two
first chapters is to introduce the notion of Vari a tional Inequality and give some
applications from physical mathematics. The third chapter is concerned with a regularity
theory for the obstacle problems. These problems have now invaded a large domain of applied
mathematics including optimal control theory and mechanics, and a collection of regularity
results available seems to be timely. Roughly speaking, for elliptic variational
inequalities of second order we prove that the solution has as much regularity as the
obstacle(s). We combine here the theory for one or two obstacles in a unified way, and one
of our hopes is that the reader will enjoy the wide diversity of techniques used in this
approach. The fourth chapter is concerned with the dam problem. This problem has been
intensively studied during the past decade (see the books of Baiocchi-Capelol and
Kinderlehrer-Stampacchia in the references). The relationship with Variational Inequalities
has already been quoted above. The book deals with the mathematical theory of vector
variational inequalities with special reference to equilibrium problems. Such models have
been introduced recently to study new problems from mechanics, structural engineering,
networks, and industrial management, and to revisit old ones. The common feature of these
problems is that given by the presence of concurrent objectives and by the difficulty of
identifying a global functional (like energy) to be extremized. The vector variational
inequalities have the advantage of both the variational ones and vector optimization which
are found as special cases. Among several applications, the equilibrium flows on a network
receive special attention. Audience: The book is addressed to academic researchers as well
as to students in the fields of pure and applied mathematics, engineering mathematics, in scientific
journalism, operations research, computer science, and economics. The essential aim of
this book is to consider a wide set of problems arising in the mathematical modeling of
mechanical systems under unilateral constraints. In these investigations elastic and non-
elastic deformations, friction and adhesion phenomena are taken into account. All the
necessary mathematical tools are given: local boundary value problem formulations,
construction of variational equations and inequalities and their transition to minimization
problems, existence and uniqueness theorems, and variational transformations (Friedrichs
and Young-Fenchel-Moreau) to dual and saddle-point search problems. This book includes a
self-contained theory of inequality problems and their applications to unilateral
mechanics. Fundamental theoretical results and related methods of analysis are discussed on
various examples and applications in mechanics. The work can be seen as a book of applied
nonlinear analysis entirely devoted to the study of inequality problems, i.e. variational
inequalities and hemivariational inequalities in mathematical models and their
applications to unilateral mechanics. It contains a systematic investigation of the interplay between theoretical results and concrete problems in mechanics. It is the
first textbook including a comprehensive and systematic study of both elliptic, parabolic
and hyperbolic inequality models, dynamical unilateral systems and unilateral eigenvalues
problems. The book is self-contained and it offers, for the first time, the possibility to
learn about inequality models and to acquire the essence of the theory in a relatively
short time. Equilibrium is a concept used in operations research and economics to understand
the interplay of factors and problems arising from competitive systems in the economic
world. The problems in this area are large and complex and have involved a variety of
mathematical methodologies. In this monograph, the authors have widened the scope of
theoretical work with a new approach, 'projected dynamical systems theory', to previous
work in variational inequality theory. While most classical work in this area is static,
the introduction to the theory of projected dynamical systems will allow many real-life
dynamic situations and problems to be handled and modeled. This monograph includes: a new
theoretical approach, 'projected dynamical system', which allows the researcher to model
real-life situations and accurately new mathematical methods, allowing researchers to
combine other theoretical approaches with the projected dynamical systems approach; a
framework in which research can adequately model natural, financial and human (real life)
situations in competitive equilibrium problems; the computational and numerical methods for
the implementation of the methods and theory discussed in the book; stability analysis,
algorithms and computational procedures are offered for each set of applications. This book
presents the mathematical theory of vector variational inequalities and their relations
with vector optimization problems. It is the first-ever book to introduce well-posedness
and sensitivity analysis for vector equilibrium problems. The first chapter provides basic
notations and results from the areas of convex analysis, functional analysis, set-valued
analysis and fixed-point theory for set-valued maps, as well as a brief introduction to
variational inequalities and equilibrium problems. Chapter 2 presents an overview of
analysis over cones, including continuity and convexity of vector-valued functions. The
book then shifts its focus to solution concepts and classical methods in vector
optimization. It describes the formulation of vector variational inequalities and their
applications to vector optimization, followed by separate chapters on linear scalarization, nonsmooth and generalized vector variational inequalities. Lastly, the book introduces readers to vector equilibrium problems and generalized vector equilibrium problems. Written in an illustrative and reader-friendly way, the book offers a valuable resource for all researchers whose work involves optimization and vector optimization. The aim of the present book is the formulation, mathematical study and numerical treatment of static and dynamic problems in mechanics and engineering sciences involving nonconvex and nonsmooth energy functions, or nonmonotone and multivalued stress-strain laws. Such problems lead to a new type of variational forms, the hemivariational inequalities, which also lead to multivalued differential or integral equations. Innovative numerical methods are presented for the treatment of realistic engineering problems. This book is the first to deal with variational theory of engineering problems involving nonmonotone multivalued realizations, their mechanical foundation, their mathematical study (existence and certain approximation results) and the corresponding eigenvalue and optimal control problems. All the numerical applications give innovative answers to as yet unsolved or partially solved engineering problems, e.g., the adhesive contact in cracks, the delamination problem, the sawtooth stress-strain laws in composites, the shear connectors in composite beams, the semirigid connections in steel structures, the adhesive grasping in robotics, etc. The book closes with the consideration of hemivariational inequalities for fractal type geometries and with the neural network approach to the numerical treatment of hemivariational inequalities. Applications of Variational Inequalities in Stochastic Control Since the publication of the first edition of Network Economics: A Variational Inequality Approach in 1993, there have been many adances in both methodological developments, as well as, applications in this field. These have occurred in an environment of an increasingly networked economic and social systems, in which the importance of transport, national networks, and communication networks is now well-recognized, with networks such as knowledge networks, environmental networks, and financial networks receiving growing attention. This edition adds recent research progress in new and evolving areas of network economics through common and unifying principles. In addition, it includes dynamic models of traffic, of spatially separated markets, of oligopolistic markets, and of financial markets. In order to expand the range and reach of this material, we have also included a series of problems in an appendix for self-study purposes and for use in the classroom. We note that computational economics has been at the forefront in stimulating the development of mathematical methodologies for the analysis and solution of complex, large-scale problems. The past fifteen years, in particular, have witnessed a dramatic growth of interest in this area. Supported by the increasing availability of data and by advances in computer architectures, the scale and dimensions of problems that can now be handled are unveiling new horizons in both theoretical modeling and policy analysis. Until now, no book addressed convexity, monotonicity, and variational inequalities together. Generalized Convexity, Nonsmooth Variational Inequalities, and Nonsmooth Optimization covers all three topics, including new variational inequality problems defined by a bifunction. The first part of the book focuses on generalized convexity and generalized monotonicity. The authors investigate convexity and generalized convexity for both the differentiable and nondifferentiable case. For the nondifferentiable case, they introduce the concepts in terms of a bifunction and the Clarke subdifferential. The second part offers insight into variational inequalities and optimization problems in smooth as well as nonsmooth settings. The book discusses existence and uniqueness criteria for a variational inequality, the gap function associated with it, and numerical methods to solve it. It also examines characterizations of a solution set of an optimization problem and explores variational inequalities defined by a bifunction and set-valued version given in terms of the Clarke subdifferential. Integrating results on convexity, monotonicity, and variational inequalities into one unified source, this book deepens your understanding of various classes of problems, such as systems of nonlinear equations, optimization problems, complementarity problems, and fixed-point problems. The book shows how variational inequality theory not only serves as a tool for formulating a variety of equilibrium problems, but also provides algorithms for computational purposes. This comprehensive volume covers a wide range of duality topics ranging from simple ideas in network flows to complex issues in non-convex optimization and multicriteria problems. In addition, it examines duality in the context of variational inequalities and vector variational inequalities, as generalizations to optimization. Duality in Optimization and Variational Inequalities is intended for researchers and practitioners of optimization with the aim of enhancing their understanding of duality. It provides a wider appreciation of optimality conditions in various scenarios and under different assumptions. It will enable the reader to use duality to devise more effective computational methods, and to aid more meaningful interpretation of optimization and variational inequality problems. Quadratic programming (QP) is one advanced mathematical technique that allows for the optimization of a quadratic function in several variables in the presence of linear constraints. This book presents recently developed algorithms for solving large QP problems and focuses on algorithms which are, in
follow, and well-referenced, this work treats almost entirely VIs of the second kind, with aspects of several classes of variational inequalities (VIs). Clearly presented, easy to viscoelastic materials. It focuses on the essentials with respect to the qualitative in contact mechanics, emphasizing antiplane frictional contact with linearly elastic and a suitably extended sub-supersolution method. This book is motivated by stimulating problems and their applications to unilateral mechanics. Fundamental theoretical results contain monograph can serve as an introductory text on quadratic programming for graduate students and researchers. Additionally, since the solution of many nonlinear problems can be reduced to the solution of a sequence of QP problems, it can also be used as a convenient introduction to nonlinear programming. This is part one of a two-volume work presenting a comprehensive treatment of the finite-dimensional variational inequality and complementarity problem. It covers the basic theory of finite dimensional variational inequalities and complementarity problems. Coverage includes abundant exercises as well as an extensive bibliography. The book will be an enduring reference on the subject and provide the foundation for its sustained growth. This Volume contains the (refereed) papers presented at the 38th Conference of the School of Mathematics “G. Stampacchia” of the “E. Majorana” Centre for Scientific Culture of Erice (Sicily), held in Memory of G. Stampacchia and J.-L. Lions in the period June 20 - July 2003. The presence of participants from Countries has greatly contributed to the success of the meeting. The School of Mathematics was dedicated to Stampacchia, not only for his great mathematical achievements, but also because He founded it. The core of the Conference has been the various features of the Variational Analysis and their motivations and applications to concrete problems. Variational Analysis encompasses a large area of modern Mathematics, such as the classical Calculus of Variations, the theories of perturbation, approximation, subgradient, subderivatives, set convergence and Variational Inequalities, and all these topics have been deeply and intensely dealt during the Conference. In particular, Variational Inequalities, which were initially inspired by Signorini Problem and the related work of G. Fichera, have offered a very great possibility of applications to several fundamental problems of Mathematical Physics, Engineering, Statistics and Economics. The pioneer work of Stampacchia and Lions can be considered as the basic kernel around which Variational Analysis is going to be outlined and constructed. The Conference has dealt with both finite and infinite dimensional analysis, showing that to carry on these two aspects disjointly is unsuitable for both. The idea for this book was developed in the seminar on problems of continuum mechanics, which has been active for more than twelve years at the Faculty of Mathematics and Physics, Charles University, Prague. This seminar has been pursuing recent directions in the development of mathematical applications, especially in continuum mechanics, and in technology. It has regularly been attended by upper division and graduate students, faculty, and scientists and researchers from various institutions from Prague and elsewhere. These seminar participants decided to publish in a self-contained monograph the results of their individual and collective efforts in developing applications to the theory of variational inequalities, which is currently a rapidly growing branch of modern analysis. The theory of variational inequalities is a relatively young mathematical discipline. Apparently, one of the main bases for its development was the paper by G. Fichera (1964) on the solution of the Signorini problem in the theory of elasticity. Later, J. L. Lions and G. Stampacchia (1967) laid the foundations of the theory itself. Time-dependent inequalities have primarily been treated in works of J. L. Lions and H. Bnlzis. The diverse applications of the variational in equalities theory are the topics of the well-known monograph by G. Du vaut and J. L. Lions, Les inuations en micanique et en physique (1972). This book includes a self-contained theory of inequality problems and their applications to unilateral mechanics. Fundamental theoretical results and related methods of analysis are discussed on various examples and applications in mechanics. The work can be seen as a book of applied nonlinear analysis entirely devoted to the study of inequality problems, i.e., variational inequalities and hemivariational inequalities in mathematical models and their corresponding applications to unilateral mechanics. It contains a systematic investigation of the interplay between theoretical results and concrete problems in mechanics. It is the first text book including a comprehensive and systematic study of both elliptic, parabolic and hyperbolic inequality models, dynamical unilateral systems and unilateral eigenvalues problems. The book is self-contained and it offers, for the first time, the possibility to learn about inequality models and to acquire the essence of the theory in a relatively short time. Audience: The book is suitable for researchers, and for doctoral and post-doctoral courses. This monograph focuses primarily on nonsmooth variational problems that arise from boundary value problems with nonsmooth data and/or nonsmooth constraints, such as multivalued elliptic problems, variational inequalities, hemivariational inequalities, and their corresponding evolution problems. It provides a systematic and unified exposition of comparison principles based on a suitably extended sub-supersolution method. This book is motivated by stimulating problems in contact mechanics, emphasizing antiplane frictional contact with linearly elastic and viscoelastic materials. It focuses on the essentials with respect to the qualitative aspects of several classes of variational inequalities (VIs). Clearly presented, easy to follow, and well-referenced, this work treats almost entirely VIs of the second kind, with
much of the material being state-of-the-art. The aim of the book is to cover the three
fundamental aspects of research in equilibrium problems: the statement problem and its
formulation using mainly variational methods, its theoretical solution by means of
classical and new variational tools, the calculus of solutions and applications in concrete
cases. The book shows how many equilibrium problems follow a general law (the so-called
user equilibrium condition). Such law allows us to express the problem in terms of
variation inequalities. Variational inequalities provide a powerful methodology, by which
existence and calculation of the solution can be obtained. This is part one of a two-volume
work presenting a comprehensive treatment of the finite-dimensional variational inequality
and complementarity problem. It covers the basic theory of finite dimensional variational
inequalities and complementarity problems. Coverage includes abundant exercises as well as
an extensive bibliography. The book will be an enduring reference on the subject and
provide the foundation for its sustained growth. A comprehensive treatment of semismooth
Newton methods in function spaces: from their foundations to recent progress in the field.
This book is appropriate for researchers and practitioners in PDE-constrained optimization,
nonlinear optimization and numerical analysis, as well as engineers interested in the
current theory and methods for solving variational inequalities. Unabridged republication is
a resource for topics in elliptic equations and systems and free boundary problems. Gives a
complete and rigorous presentation of the mathematical study of the expressions -
hemivariational inequalities - arising in problems that involve nonconvex, nonsmooth energy
functions. A theory of the existence of solutions for inequality problems involving
monconvexity and nonsmoothness is established. Equilibrium is a concept used in operations
research and economics to understand the interplay of factors and problems arising from
competitive systems in the economic world. The problems in this area are large and complex
and have many possible approaches. The monograph introduces a general fixed point principle and its application to various nonlinear
history-dependent operators are exposed in a large generality. A systematic and unified
application to solid and contact mechanics. Based on authors' original results, it
introduces a general fixed point principle and its application to various nonlinear
problems in analysis and mechanics. The classes of history-dependent operators and almost
history-dependent operators are exposed in a large generality. A systematic and unified
presentation contains a carefully-selected collection of new results on variational-
hemivariational inequalities with or without unilateral constraints. A wide spectrum of
static, quasistatic, dynamic contact problems for elastic, viscoelastic and viscoplastic
materials illustrates the applicability of these theoretical results. Written for
mathematicians, applied mathematicians, engineers and scientists, it is also a valuable
tool for graduate students and researchers in nonlinear analysis, mathematical modelling,
mechanics of solids, and contact mechanics. The concept of equilibrium plays a central role
in various applied sciences, such as physics (especially, mechanics), economics,
enGINEERING, transportation, sociology, chemistry, biology and other fields. If one can
formulate the equilibrium problem in the form of a mathematical model, solutions of the
corresponding problem can be used for forecasting the future behavior of very complex
systems and, also, for correcting the current state of the system under control. This
book presents a unifying look on different equilibrium concepts in economics, including
several models from related sciences. - Presents a unifying look on different equilibrium
concepts and also the present state of investigations in this field - Describes static and
dynamic input-output models, Walras, Cassel-Wald, spatial price, auction market,
oligopolistic equilibrium models, transportation and migration equilibrium models - Covers
the basics of theory and solution methods both for the complementarity and variational
inequality problems - The methods are illustrated by applications and exercises to economic
equilibrium models - Uncertainty Quantification (UQ) is an emerging and extremely active
research discipline which aims to quantitatively delineate any uncertainty in applied
models. The primary objective of this book is to present a comprehensive treatment of
uncertainty quantification in variational inequalities (and some of its generalizations
such as quasi-variational inequalities) emerging from various network, economic, and
engineering models. This volume brings forth a set of papers presented at the conference on
"Variational Inequalities and Network Equilibrium problems", held in Erice at the "G. Stam
Variational Inequalities With Applications: A Study Of Antiplane Frictional Contact Problems

Advances in Mechanics and Mathematics

Pacchiai School of the "E. Majorana" Centre for Scientific Culture in the period 19-25 June 1994. The meeting was conceived to contribute to the exchange between Variational Analysis and equilibrium problems, especially those related to network design. Most of the approaches and viewpoints of these fields are present in the volume, both as concerns the theory and the applications of equilibrium problems to transportation, computer and electric networks, to market behavior, and to bi-level programming. Being convinced of the great importance of equilibrium problems as well as of their complexity, the organizers hope that the merging of points of view coming from different fields will stimulate theoretical research and applications. In this context Variational and Quasi-Variational Inequalities have shown themselves to be very important models for equilibrium problems. As a consequence in the last two decades they have received a lot of attention both as to mathematical investigation and applications. The proof that the above mentioned equilibrium problems can be expressed, in terms of Variational or Quasi-Variational Inequalities also in the non-standard and non-symmetric cases, has been a crucial improvement.

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