

Nonsmooth mechanics for general relativity

Ding Jia (贾丁)
djia.research@gmail.com
<https://ttoe.in>

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Abstract: We study relativistic matter and gravitational fields subject to inequality constraints. Conditions are derived for solutions to the action principle as local extrema of the action. In regions where constraints remain inactive, the fields satisfy the standard Euler-Lagrange equations. On hypersurfaces where constraints are activated, field derivatives can jump discontinuously in order to obey the constraints. For matter fields, energy-momentum flux is conserved across the hypersurfaces. For gravitational fields, boundary terms in the action that cancel in smooth mechanics are not guaranteed to canceled across the hypersurface. The resulting theory allows solutions to extend beyond gravitational singularities.



Topics In Nonsmooth Mechanics

J.J. Moreau, P.D. Panagiotopoulos



Topics In Nonsmooth Mechanics:

Topics in Nonsmooth Mechanics Jean Jacques Moreau, P. D. Panagiotopoulos, Gilbert Strang, 1988

Nonsmooth Mechanics of Solids Jaroslav Haslinger, Georgios E. Stavroulakis, 2007-08-03

Mechanics have played an important role in mathematics from infinitesimal calculus calculus of variations partial differential equations and numerical methods finite elements Originally mechanics treated smooth objects Technological progress has evoked the necessity to model and solve more complicated problems like unilateral contact and friction plasticity delamination and adhesion advanced materials etc The new tools include convex analysis differential calculus for convex functions and subgradients of convex functions and extensions for nonconvex problems Nonsmooth mechanics is a relatively complex field and requires a good knowledge of mechanics and a good background in some parts of modern mathematics The present volume of lecture notes follows a very successful advanced school with the aim to cover as much as possible all these aspects Therefore the contributions cover mechanical aspects as well as the mathematical and numerical treatment

Nonsmooth Mechanics Bernard Brogliato, 2012-12-06 Thank you for opening the second edition of this monograph which is devoted to the study of a class of nonsmooth dynamical systems of the general form $\dot{x} = f(x, u)$ where $x \in \mathbb{R}^n$ is the system's state vector $u \in \mathbb{R}^m$ is the vector of inputs and the function f represents a unilateral constraint that is imposed on the state More precisely we shall restrict ourselves to a subclass of such systems namely mechanical systems subject to unilateral constraints on the position whose dynamical equations may be in a first instance written as $\ddot{q} = g(q, \dot{q}, u)$ where $q \in \mathbb{R}^n$ is the vector of generalized coordinates of the system and u is an input or controller that generally involves a state feedback loop i.e. $u = u(q, \dot{q}, t)$ with $z = z(q, \dot{q}, t)$ when the controller is a dynamic state feedback Mechanical systems composed of rigid bodies interacting fall into this subclass A general property of systems as in 0.1 and 0.2 is that their solutions are nonsmooth with respect to time Nonsmoothness arises primarily from the occurrence of impacts or collisions or percussions in the dynamical behaviour when the trajectories attain the surface $f(x, t) = 0$ They are necessary to keep the trajectories within the subspace $\{x \mid f(x, t) \leq 0\}$ of the system's state space

Semi-Rigid Joints in Structural Steelwork Miklos Ivanyi, Charalambos C. Baniotopoulos, 2014-05-04 Definition of semi rigid steel structural connections classification and influence to the structural response of sway and non sway steel frames Sources of connection compliance ductility and the application of the component method for characterization of the joint properties Verification procedures for the available and the required capacity of joints and the design of semi rigid steel structural connections Application of the Finite Element Method for the simulation of the structural response of semi rigid connections taking into account all prominent nonlinear phenomena cf e.g. contact friction and plasticity

Multibody Dynamics Krzysztof Arczewski, Wojciech Blajer, Janusz Fraczek, Marek Wojtyra, 2010-11-08 The ECCOMAS Thematic Conference Multibody Dynamics 2009 was held in Warsaw representing the fourth edition of a series which began in Lisbon 2003 and was then continued in Madrid 2005 and Milan 2007 held under the

auspices of the European Community on Computational Methods in Applied Sciences ECCOMAS The conference provided a forum for exchanging ideas and results of several topics related to computational methods and applications in multibody dynamics through the participation of 219 scientists from 27 countries mostly from Europe but also from America and Asia This book contains the revised and extended versions of invited conference papers reporting on the state of the art in the advances of computational multibody models from the theoretical developments to practical engineering applications By providing a helpful overview of the most active areas and the recent efforts of many prominent research groups in the field of multibody dynamics this book can be highly valuable for both experienced researchers who want to keep updated with the latest developments in this field and researchers approaching the field for the first time

A Smooth and Discontinuous Oscillator Qingjie Cao, Alain Léger, 2016-09-27 This is the first book to introduce the irrational elliptic function series providing a theoretical treatment for the smooth and discontinuous system and opening a new branch of applied mathematics The discovery of the smooth and discontinuous SD oscillator and the SD attractors discussed in this book represents a further milestone in nonlinear dynamics following on the discovery of the Ueda attractor in 1961 and Lorenz attractor in 1963 This particular system bears significant similarities to the Duffing oscillator exhibiting the standard dynamics governed by the hyperbolic structure associated with the stationary state of the double well However there is a substantial departure in nonlinear dynamics from standard dynamics at the discontinuous stage The constructed irrational elliptic function series which offers a way to directly approach the nature dynamics analytically for both smooth and discontinuous behaviours including the unperturbed periodic motions and the perturbed chaotic attractors without any truncation is of particular interest Readers will also gain a deeper understanding of the actual nonlinear phenomena by means of a simple mechanical model the theory methodology and the applications in various interlinked disciplines of sciences and engineering This book offers a valuable resource for researchers professionals and postgraduate students in mechanical engineering non linear dynamics and related areas such as nonlinear modelling in various fields of mathematics physics and the engineering sciences

Nonsmooth Mechanics and Analysis Pierre Alart, Olivier Maier, R. Tyrrell Rockafellar, 2005-11-17 This book's title Nonsmooth Mechanics and Analysis refers to a major domain of mechanics particularly those initiated by the works of Jean Jacques Moreau Nonsmooth mechanics concerns mechanical situations with possible nondifferentiable relationships eventually discontinuous as unilateral contact dry friction collisions plasticity damage and phase transition The basis of the approach consists in dealing with such problems without resorting to any regularization process Indeed the nonsmoothness is due to simplified mechanical modeling a more sophisticated model would require too large a number of variables and sometimes the mechanical information is not available via experimental investigations Therefore the mathematical formulation becomes nonsmooth regularizing would only be a trick of arithmetic without any physical justification Nonsmooth analysis was developed especially in Montpellier to provide specific theoretical and numerical tools

to deal with nonsmoothness It is important not only in mechanics but also in physics robotics and economics Audience This book is intended for researchers in mathematics and mechanics **Nonsmooth/Nonconvex Mechanics** David Yang Gao, Raymond W. Ogden, Georgios E. Stavroulakis, 2013-12-01 Nonsmooth and nonconvex models arise in several important applications of mechanics and engineering The interest in this field is growing from both mathematicians and engineers The study of numerous industrial applications including contact phenomena in statics and dynamics or delamination effects in composites require the consideration of nonsmoothness and nonconvexity The mathematical topics discussed in this book include variational and hemivariational inequalities duality complementarity variational principles sensitivity analysis eigenvalue and resonance problems and minimax problems Applications are considered in the following areas among others nonsmooth statics and dynamics stability of quasi static evolution processes friction problems adhesive contact and debonding inverse problems pseudoelastic modeling of phase transitions chaotic behavior in nonlinear beams and nonholonomic mechanical systems This volume contains 22 chapters written by various leading researchers and presents a cohesive and authoritative overview of recent results and applications in the area of nonsmooth and nonconvex mechanics Audience Faculty graduate students and researchers in applied mathematics optimization control and engineering **A Variational Approach to Nonsmooth Dynamics** Samir Adly, 2018-02-19 This brief examines mathematical models in nonsmooth mechanics and nonregular electrical circuits including evolution variational inequalities complementarity systems differential inclusions second order dynamics Lur e systems and Moreau s sweeping process The field of nonsmooth dynamics is of great interest to mathematicians mechanicians automatic controllers and engineers The present volume acknowledges this transversality and provides a multidisciplinary view as it outlines fundamental results in nonsmooth dynamics and explains how to use them to study various problems in engineering In particular the author explores the question of how to redefine the notion of dynamical systems in light of modern variational and nonsmooth analysis With the aim of bridging between the communities of applied mathematicians engineers and researchers in control theory and nonlinear systems this brief outlines both relevant mathematical proofs and models in unilateral mechanics and electronics **Advances in Materials and Systems Technologies III** Akii Okonigbon Akaehomen Ibadode, 2011-10-24 Selected peer reviewed papers from the Third International Conference on Engineering Research and Development Advances in Engineering Science and Technology ICERD 2010 held at the University of Benin Benin City Nigeria in September 7 9 2010 **Minimax Theorems and Qualitative Properties of the Solutions of Hemivariational Inequalities** Dumitru Motreanu, P. D. Panagiotopoulos, 1999 The present book is the first ever published in which a new type of eigenvalue problem is studied one that is very useful for applications eigenvalue problems related to hemivariational inequalities i e involving nonsmooth nonconvex energy functions New existence multiplicity and perturbation results are proved using three different approaches minimization minimax methods and sub critical point theory Nonresonant and resonant cases are studied both

for static and dynamic problems and several new qualitative properties of the hemivariational inequalities are obtained Both simple and double eigenvalue problems are studied as well as those constrained on the sphere and those which are unconstrained The book is self contained is written with the utmost possible clarity and contains highly original results Applications concerning new stability results for beams plates and shells with adhesive supports etc illustrate the theory Audience applied and pure mathematicians civil aeronautical and mechanical engineers Philosophical Transactions of the Royal Society ,2001 *Nonsmooth Mechanics and Applications* J.J. Moreau,P.D. Panagiotopoulos,2014-05-04

Publicationes mathematicae Kossuth Lajos Tudományegyetem. Matematikai Intézet,1989 **Large Scale Optimization** William W. Hager,D.W. Hearn,Panos M. Pardalos,1994-05-31 This book is a collection of papers presented at the Large Scale Optimization Conference held at the Center for Applied Optimization University of Florida Gainesville in February 1993 Accurate modelling of scientific problems often leads to the formulation of large scale optimization problems involving thousands of continuous and or discrete variables As a consequence of new algorithmic developments and of the increased power of computers large scale optimization has seen a dramatic increase in activities in the past decade Topics include large scale linear nonlinear and stochastic programming network optimization decomposition methods methods for optimal control nonsmooth equations integer programming and software development In addition applications are included in location theory structural mechanics molecular configuration transportation multitarget tracking and database design The book is a valuable source of information for faculty students and researchers in mathematical programming and related fields

Physics Briefs ,1991 **2017 Constructive Nonsmooth Analysis and Related Topics (dedicated to the Memory of V F Demyanov) (CNSA)** IEEE Staff,2017-05-22 The objective of the conference is to bring together mathematicians physicists and engineers to present and discuss recent developments in the area of mathematical control methods modelling and nonsmooth optimization The conference scope includes the following areas the design tools of nonsmooth analysis nonsmooth problems of variational calculus and control theory nonsmooth mechanics problem nondifferentiable optimization nonsmooth analysis applications mathematical modeling mathematical problems of diagnostics methods of game theory nonlinear Chebyshev approximation and optimization Constructive Nonsmooth Analysis and Related Topics Vladimir F. Demyanov,Panos M. Pardalos,Mikhail Batsyn,2013-11-12 This volume contains a collection of papers based on lectures and presentations delivered at the International Conference on Constructive Nonsmooth Analysis CNSA held in St Petersburg Russia from June 18 23 2012 This conference was organized to mark the 50th anniversary of the birth of nonsmooth analysis and nondifferentiable optimization and was dedicated to J J Moreau and the late B N Pshenichnyi A M Rubinov and N Z Shor whose contributions to NSA and NDO remain invaluable The first four chapters of the book are devoted to the theory of nonsmooth analysis Chapters 5 8 contain new results in nonsmooth mechanics and calculus of variations Chapters 9 13 are related to nondifferentiable optimization and the volume concludes with four chapters containing interesting and important

historical chapters including tributes to three giants of nonsmooth analysis convexity and optimization Alexandr Alexandrov Leonid Kantorovich and Alex Rubinov The last chapter provides an overview and important snapshots of the 50 year history of convex analysis and optimization *Phase Interaction in Composite Materials* S. A. Paipetis,George Papanicolaou,1992
Advances in Nonlinear Variational Inequalities ,2004

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Table of Contents Topics In Nonsmooth Mechanics

1. Understanding the eBook Topics In Nonsmooth Mechanics
 - The Rise of Digital Reading Topics In Nonsmooth Mechanics
 - Advantages of eBooks Over Traditional Books
2. Identifying Topics In Nonsmooth Mechanics
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Topics In Nonsmooth Mechanics
 - User-Friendly Interface
4. Exploring eBook Recommendations from Topics In Nonsmooth Mechanics
 - Personalized Recommendations
 - Topics In Nonsmooth Mechanics User Reviews and Ratings
 - Topics In Nonsmooth Mechanics and Bestseller Lists
5. Accessing Topics In Nonsmooth Mechanics Free and Paid eBooks
 - Topics In Nonsmooth Mechanics Public Domain eBooks
 - Topics In Nonsmooth Mechanics eBook Subscription Services
 - Topics In Nonsmooth Mechanics Budget-Friendly Options

6. Navigating Topics In Nonsmooth Mechanics eBook Formats
 - ePub, PDF, MOBI, and More
 - Topics In Nonsmooth Mechanics Compatibility with Devices
 - Topics In Nonsmooth Mechanics Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Topics In Nonsmooth Mechanics
 - Highlighting and Note-Taking Topics In Nonsmooth Mechanics
 - Interactive Elements Topics In Nonsmooth Mechanics
8. Staying Engaged with Topics In Nonsmooth Mechanics
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Topics In Nonsmooth Mechanics
9. Balancing eBooks and Physical Books Topics In Nonsmooth Mechanics
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Topics In Nonsmooth Mechanics
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Topics In Nonsmooth Mechanics
 - Setting Reading Goals Topics In Nonsmooth Mechanics
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Topics In Nonsmooth Mechanics
 - Fact-Checking eBook Content of Topics In Nonsmooth Mechanics
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements

- Interactive and Gamified eBooks

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