

Optimal Control



- Optimal control problems are hard
 - Infinite-dimensional, non-convex in general
- Linear quadratic problems are solvable

$$\text{minimize } \int_0^{\infty} (x^T(t) Q_x x(t) + u^T(t) Q_u u(t)) dt$$

$$\begin{aligned} \text{subject to } \quad & \dot{x} = Ax + Bu & x &\in R^n \\ & y = Cx & u &\in R^m \\ & & y &\in R^p \end{aligned}$$

Problems And Methods Of Optimal Control

Hans P. Geering



Problems And Methods Of Optimal Control:

Numerical Methods for Optimal Control Problems Maurizio Falcone, Roberto Ferretti, Lars Grüne, William M. McEneaney, 2019-01-26 This work presents recent mathematical methods in the area of optimal control with a particular emphasis on the computational aspects and applications Optimal control theory concerns the determination of control strategies for complex dynamical systems in order to optimize some measure of their performance Started in the 60 s under the pressure of the space race between the US and the former USSR the field now has a far wider scope and embraces a variety of areas ranging from process control to traffic flow optimization renewable resources exploitation and management of financial markets These emerging applications require more and more efficient numerical methods for their solution a very difficult task due the huge number of variables The chapters of this volume give an up to date presentation of several recent methods in this area including fast dynamic programming algorithms model predictive control and max plus techniques This book is addressed to researchers graduate students and applied scientists working in the area of control problems differential games and their applications

Problems and Methods of Optimal Control L.D. Akulenko, 2011-10-06 The numerous applications of optimal control theory have given an incentive to the development of approximate techniques aimed at the construction of control laws and the optimization of dynamical systems These constructive approaches rely on small parameter methods averaging regular and singular perturbations which are well known and have been proven to be efficient in nonlinear mechanics and optimal control theory maximum principle variational calculus and dynamic programming An essential feature of the procedures for solving optimal control problems consists in the necessity for dealing with two point boundary value problems for nonlinear and as a rule nonsmooth multi dimensional sets of differential equations This circumstance complicates direct applications of the above mentioned perturbation methods which have been developed mostly for investigating initial value Cauchy problems There is now a need for a systematic presentation of constructive analytical per turbation methods relevant to optimal control problems for nonlinear systems The purpose of this book is to meet this need in the English language scientific literature and to present consistently small parameter techniques relating to the constructive investigation of some classes of optimal control problems which often arise in prac tice This book is based on a revised and modified version of the monograph L D Akulenko Asymptotic methods in optimal control Moscow Nauka 366 p in Russian

Numerical Methods for Optimal Control Problems with State Constraints Radoslaw Pytlak, 2006-11-14 While optimality conditions for optimal control problems with state constraints have been extensively investigated in the literature the results pertaining to numerical methods are relatively scarce This book fills the gap by providing a family of new methods Among others a novel convergence analysis of optimal control algorithms is introduced The analysis refers to the topology of relaxed controls only to a limited degree and makes little use of Lagrange multipliers corresponding to state constraints This approach enables the author to provide global convergence analysis of first order and

superlinearly convergent second order methods Further the implementation aspects of the methods developed in the book are presented and discussed The results concerning ordinary differential equations are then extended to control problems described by differential algebraic equations in a comprehensive way for the first time in the literature Computational Methods in Optimal Control Problems I.H. Mufti,2012-12-06 The purpose of this modest report is to present in a simplified manner some of the computational methods that have been developed in the last ten years for the solution of optimal control problems Only those methods that are based on the minimum maximum principle of Pontriagin are discussed here The outline of the report is as follows In the first two sections a control problem of Bolza is formulated and the necessary conditions in the form of the minimum principle are given The method of steepest descent and a conjugate gradient method are discussed in Section 3 In the remaining sections the successive sweep method the Newton Raphson method and the generalized Newton Raphson method also called quasilinearization method are presented from a unified approach which is based on the application of Newton Raphson approximation to the necessary conditions of optimality The second variation method and other shooting methods based on minimizing an error function are also considered

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An Introduction to Optimal Control Problems in Life Sciences and Economics Sebastian Anița,Viorel Arnăutu,Vincenzo Capasso,2011-05-05 Combining control theory and modeling this textbook introduces and builds on methods for simulating and tackling concrete problems in a variety of applied sciences Emphasizing learning by doing the authors focus on examples and applications to real world problems An elementary presentation of advanced concepts proofs to introduce new ideas and carefully presented MATLAB programs help foster an understanding of the basics but also lead the way to new independent research With minimal prerequisites and exercises in each chapter this work serves as an excellent textbook and reference for graduate and advanced undergraduate students researchers and practitioners in mathematics physics engineering computer science as well as biology biotechnology economics and finance

Global Methods in Optimal Control Theory Vadim Krotov,1995-10-13 This work describes all basic equations and inequalities that form the necessary and sufficient optimality conditions of variational calculus and the theory of optimal control Subjects addressed include developments in the investigation of optimality conditions new classes of solutions analytical and computation methods and applications

Optimal Control Bulirsch,Miele,Stoer,Well,2013-03-08 Optimal Control reports on new theoretical and practical advances essential for analysing and synthesizing optimal controls of dynamical systems governed by partial and ordinary differential equations New necessary and sufficient conditions for optimality are given Recent advances in numerical methods are discussed These have been achieved through new techniques

for solving large sized nonlinear programs with sparse Hessians and through a combination of direct and indirect methods for solving the multipoint boundary value problem The book also focuses on the construction of feedback controls for nonlinear systems and highlights advances in the theory of problems with uncertainty Decomposition methods of nonlinear systems and new techniques for constructing feedback controls for state and control constrained linear quadratic systems are presented The book offers solutions to many complex practical optimal control problems Computational Methods in Optimal Control Problems Izhar-ul H. Mufti,1970 Methods of Optimal Statistical Decisions, Optimal Control, and Stochastic Differential Equations Ellida M. Khazen,2009-11-16 This book provides the reader with some insight into the mathematical models of random processes with continuous time stochastic differential equations and stochastic integrals An advanced development of the mathematical methods of optimal statistical decisions statistical sequential analysis and informational estimation of risks and new methods and solutions to the important problems of the theory of optimal control are presented The new original results obtained by this author and published shortly in her numerous scientific research papers are presented in a systematic way in this book The book is intended for engineers students post graduate students and scientist researchers The presentation of the material is accessible to engineers **Practical Methods for Optimal Control and Estimation Using Nonlinear Programming** John T. Betts,2010-01-01 A focused presentation of how sparse optimization methods can be used to solve optimal control and estimation problems Operator Methods for Optimal Control Problems Whei-Mei Lee,1987-08-31 **A Unified Computational Approach to Optimal Control Problems** K. L. Teo,Chuen-Jin Goh,Kar-Hung Wong,1991 Concerned with optimal control theory this text aims to supplement existing work in this field from the viewpoints of computation and applications In particular those computational algorithms derived from the concept of control parametrization are emphasized in this text **Optimal Control Theory** Suresh P. Sethi,Gerald L. Thompson,2000-07-31 Optimal control methods are used to determine optimal ways to control a dynamic system The theoretical work in this field serves as a foundation for the book which the authors have applied to business management problems developed from their research and classroom instruction Sethi and Thompson have provided management science and economics communities with a thoroughly revised edition of their classic text on Optimal Control Theory The new edition has been completely refined with careful attention to the text and graphic material presentation Chapters cover a range of topics including finance production and inventory problems marketing problems machine maintenance and replacement problems of optimal consumption of natural resources and applications of control theory to economics The book contains new results that were not available when the first edition was published as well as an expansion of the material on stochastic optimal control theory **Symplectic Pseudospectral Methods for Optimal Control** Xinwei Wang,Jie Liu,Haijun Peng,2020-10-16 The book focuses on symplectic pseudospectral methods for nonlinear optimal control problems and their applications Both the fundamental principles and engineering practice are addressed Symplectic pseudospectral methods for

nonlinear optimal control problems with complicated factors i.e. inequality constraints state delay unspecific terminal time etc are solved under the framework of indirect methods The methods developed here offer a high degree of computational efficiency and accuracy when compared with popular direct pseudospectral methods The methods are applied to solve optimal control problems arising in various engineering fields particularly in path planning problems for autonomous vehicles Given its scope the book will benefit researchers engineers and graduate students in the fields of automatic control path planning ordinary differential equations etc *Optimal Control Theory* Donald E. Kirk, 2004-01-01 Geared toward upper level undergraduates this text introduces three aspects of optimal control theory dynamic programming Pontryagin's

minimum principle and numerical techniques for trajectory optimization Numerous problems which introduce additional topics and illustrate basic concepts appear throughout the text Solution guide available upon request 131 figures 14 tables 1970 edition **Numerical Methods for Optimal Control Problems with State Constraints** S. Lyle, N. K. Nichols, 1991

Optimal Control of Partial Differential Equations Fredi Tröltzsch, 2010 Optimal control theory is concerned with finding control functions that minimize cost functions for systems described by differential equations The methods have found widespread applications in aeronautics mechanical engineering the life sciences and many other disciplines This book focuses on optimal control problems where the state equation is an elliptic or parabolic partial differential equation Included are topics such as the existence of optimal solutions necessary optimality conditions and adjoint equations second order sufficient conditions and main principles of selected numerical techniques It also contains a survey on the Karush Kuhn Tucker theory of nonlinear programming in Banach spaces The exposition begins with control problems with linear equations quadratic cost functions and control constraints To make the book self contained basic facts on weak solutions of elliptic and parabolic equations are introduced Principles of functional analysis are introduced and explained as they are needed Many simple examples illustrate the theory and its hidden difficulties This start to the book makes it fairly self contained and suitable for advanced undergraduates or beginning graduate students Advanced control problems for nonlinear partial differential equations are also discussed As prerequisites results on boundedness and continuity of solutions to semilinear elliptic and parabolic equations are addressed These topics are not yet readily available in books on PDEs making the exposition also interesting for researchers Alongside the main theme of the analysis of problems of optimal control Tröltzsch also discusses numerical techniques The exposition is confined to brief introductions into the basic ideas in order to give the reader an impression of how the theory can be realized numerically After reading this book the reader will be familiar with the main principles of the numerical analysis of PDE constrained optimization Publisher's description **Optimal Control Theory** Zhongjing Ma, Suli Zou, 2021-01-30 This book focuses on how to implement optimal control problems via the variational method It studies how to implement the extrema of functional by applying the variational method and covers the extrema of functional with different boundary conditions involving multiple functions and with certain constraints etc It gives

the necessary and sufficient condition for the continuous time optimal control solution via the variational method solves the optimal control problems with different boundary conditions analyzes the linear quadratic regulator tracking problems respectively in detail and provides the solution of optimal control problems with state constraints by applying the Pontryagin's minimum principle which is developed based upon the calculus of variations And the developed results are applied to implement several classes of popular optimal control problems and say minimum time minimum fuel and minimum energy problems and so on As another key branch of optimal control methods it also presents how to solve the optimal control problems via dynamic programming and discusses the relationship between the variational method and dynamic programming for comparison Concerning the system involving individual agents it is also worth to study how to implement the decentralized solution for the underlying optimal control problems in the framework of differential games The equilibrium is implemented by applying both Pontryagin's minimum principle and dynamic programming The book also analyzes the discrete time version for all the above materials as well since the discrete time optimal control problems are very popular in many fields

Optimal Control with Engineering Applications Hans P. Geering, 2007-03-23 This book introduces a variety of problem statements in classical optimal control in optimal estimation and filtering and in optimal control problems with non scalar valued performance criteria Many example problems are solved completely in the body of the text All chapter end exercises are sketched in the appendix The theoretical part of the book is based on the calculus of variations so the exposition is very transparent and requires little mathematical rigor

Optimal Control Leonid T. Aschepkov, Dmitriy V. Dolgy, Taekyun Kim, Ravi P. Agarwal, 2017-01-11 This book is based on lectures from a one year course at the Far Eastern Federal University Vladivostok Russia as well as on workshops on optimal control offered to students at various mathematical departments at the university level The main themes of the theory of linear and nonlinear systems are considered including the basic problem of establishing the necessary and sufficient conditions of optimal processes In the first part of the course the theory of linear control systems is constructed on the basis of the separation theorem and the concept of a reachability set The authors prove the closure of a reachability set in the class of piecewise continuous controls and the problems of controllability observability identification performance and terminal control are also considered The second part of the course is devoted to nonlinear control systems Using the method of variations and the Lagrange multipliers rule of nonlinear problems the authors prove the Pontryagin maximum principle for problems with mobile ends of trajectories Further exercises and a large number of additional tasks are provided for use as practical training in order for the reader to consolidate the theoretical material

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