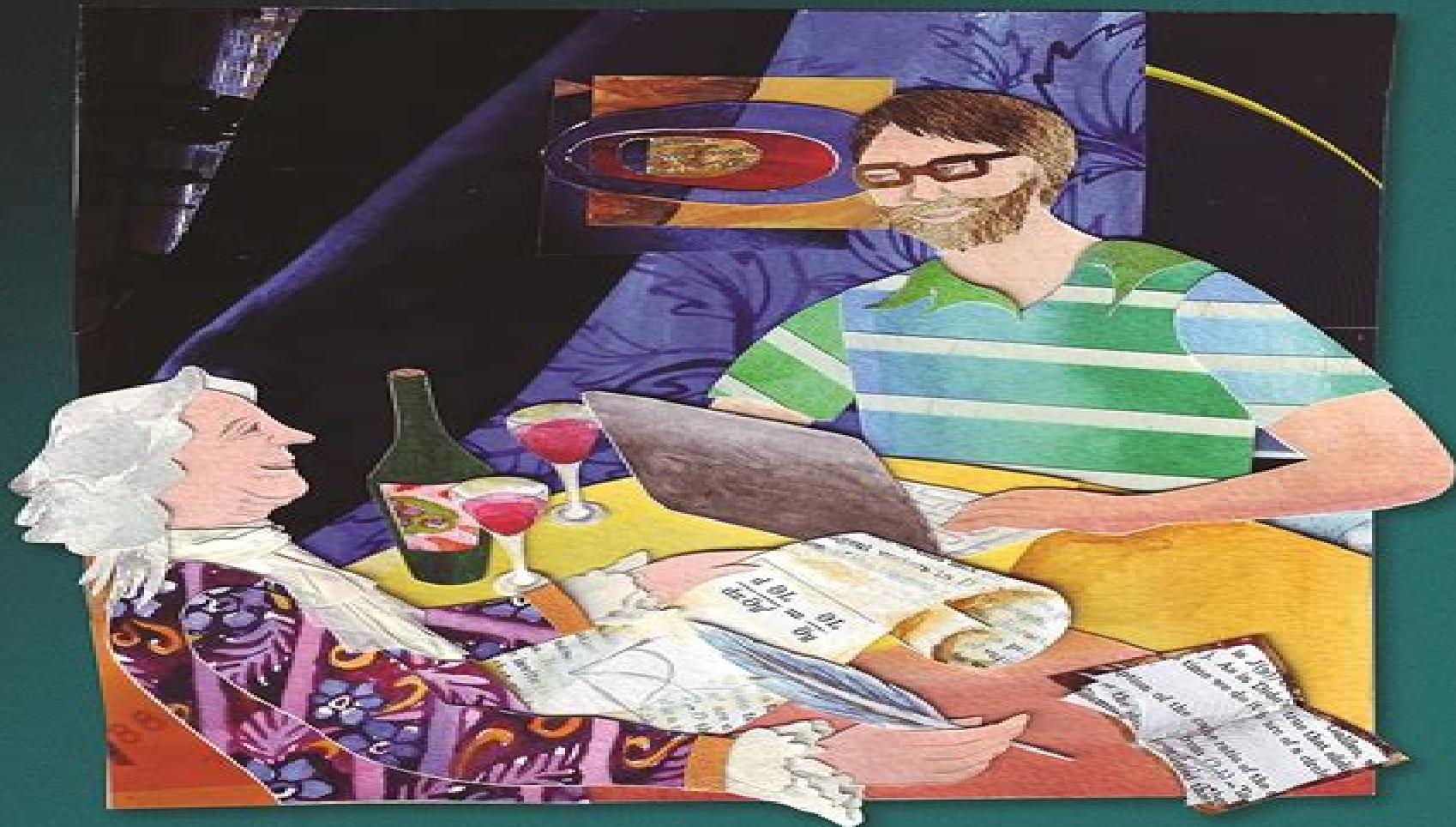


# CALCULUS OF VARIATIONS AND OPTIMAL CONTROL THEORY

A Concise Introduction



DANIEL LIBERZON

# Calculus Of Variations And Optimal Control Theory A Concise Introduction

**Pablo Pedregal**

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*Calculus of Variations and Optimal Control Theory* Daniel Liberzon, 2012-01-08 This textbook offers a concise yet rigorous introduction to calculus of variations and optimal control theory and is a self contained resource for graduate students in engineering applied mathematics and related subjects Designed specifically for a one semester course the book begins with calculus of variations preparing the ground for optimal control It then gives a complete proof of the maximum principle and covers key topics such as the Hamilton Jacobi Bellman theory of dynamic programming and linear quadratic optimal control Calculus of Variations and Optimal Control Theory also traces the historical development of the subject and features numerous exercises notes and references at the end of each chapter and suggestions for further study Offers a concise yet rigorous introduction Requires limited background in control theory or advanced mathematics Provides a complete proof of the maximum principle Uses consistent notation in the exposition of classical and modern topics Traces the historical development of the subject Solutions manual available only to teachers Leading universities that have adopted this book include University of Illinois at Urbana Champaign ECE 553 Optimum Control Systems Georgia Institute of Technology ECE 6553 Optimal Control and Optimization University of Pennsylvania ESE 680 Optimal Control Theory University of Notre Dame EE 60565 Optimal Control      Calculus of Variations and Optimal Control Theory ,2012

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brachistochrone and the minimal surface of revolution He gives a detailed discussion of the Hamilton Jacobi theory both in the parametric and nonparametric forms This leads to the development of sufficiency theories describing properties of minimizing extremal arcs Next the author addresses existence theorems He first develops Hilbert s basic existence theorem for parametric problems and studies some of its consequences Finally he develops the theory of generalized curves and automatic existence theorems In the second part of the book the author discusses optimal control problems He notes that originally these problems were formulated as problems of Lagrange and Mayer in terms of differential constraints In the control formulation these constraints are expressed in a more convenient form in terms of control functions After pointing out the new phenomenon that may arise namely the lack of controllability the author develops the maximum principle and illustrates this principle by standard examples that show the switching phenomena that may occur He extends the theory of geodesic coverings to optimal control problems Finally he extends the problem to generalized optimal control problems and obtains the corresponding existence theorems

### **The Calculus of Variations and Optimal Control**

George Leitmann,1981-05-31 This book is intended to present an introductory treatment of the calculus of variations in Part I and of optimal control theory in Part II The discussion in Part I is restricted to the simplest problem of the calculus of variations The topic is entirely classical all of the basic theory had been developed before the turn of the century Consequently the material comes from many sources

### **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

### **A Primer on the Calculus of Variations and Optimal**

Control Theory Mike Mesterton-Gibbons,2009 The calculus of variations is used to find functions that optimize quantities

expressed in terms of integrals Optimal control theory seeks to find functions that minimize cost integrals for systems described by differential equations This book is an introduction to both the classical theory of the calculus of variations and the more modern developments of optimal control theory from the perspective of an applied mathematician It focuses on understanding concepts and how to apply them The range of potential applications is broad the calculus of variations and optimal control theory have been widely used in numerous ways in biology criminology economics engineering finance management science and physics Applications described in this book include cancer chemotherapy navigational control and renewable resource harvesting The prerequisites for the book are modest the standard calculus sequence a first course on ordinary differential equations and some facility with the use of mathematical software It is suitable for an undergraduate or beginning graduate course or for self study It provides excellent preparation for more advanced books and courses on the calculus of variations and optimal control theory Introduction to Optimal Control Theory Jack Macki,Aaron

Strauss,2012-12-06 This monograph is an introduction to optimal control theory for systems governed by vector ordinary differential equations It is not intended as a state of the art handbook for researchers We have tried to keep two types of reader in mind 1 mathematicians graduate students and advanced undergraduates in mathematics who want a concise introduction to a field which contains nontrivial interesting applications of mathematics for example weak convergence convexity and the theory of ordinary differential equations 2 economists applied scientists and engineers who want to understand some of the mathematical foundations of optimal control theory In general we have emphasized motivation and explanation avoiding the definition axiom theorem proof approach We make use of a large number of examples especially one simple canonical example which we carry through the entire book In proving theorems we often just prove the simplest case then state the more general results which can be proved Many of the more difficult topics are discussed in the Notes sections at the end of chapters and several major proofs are in the Appendices We feel that a solid understanding of basic facts is best attained by at first avoiding excessive generality We have not tried to give an exhaustive list of references preferring to refer the reader to existing books or papers with extensive bibliographies References are given by author s name and the year of publication e g Waltman 1974 *Calculus of Variations and Optimal Control Theory* Magnus Rudolph Hestenes,1966

**Optimal Control** Stewart Johnson,2025-10-07 Optimal control theory concerns the study of dynamical systems where one operates a control parameter with the goal of optimizing a given payoff function This textbook provides an accessible examples led approach to the subject The text focuses on systems modeled by differential equations with applications drawn from a wide range of topics including engineering economics finance and game theory Each topic is complemented by carefully prepared exercises to enhance understanding The book begins with introductory chapters giving an overview of the subject and covering the necessary optimization techniques from calculus After this Pontryagin s method is developed for control problems on one dimensional state spaces culminating in the study of linear quadratic systems The core material is

rounded out by the consideration of higher dimensional systems The text concludes with more advanced topics such as bang bang controls and differential game theory A final chapter examines the calculus of variations giving a brief overview of the Euler Lagrange theory and general isoperimetric problems Designed for undergraduates in mathematics physics or economics Optimal Control Theory can be used in a structured course or for self study The treatment is highly accessible and only requires a familiarity with multivariable calculus differential equations and basic matrix algebra

**Constrained Optimization In The Calculus Of Variations and Optimal Control Theory** J Gregory, 2018-01-18 The major purpose of this book is to present the theoretical ideas and the analytical and numerical methods to enable the reader to understand and efficiently solve these important optimizational problems The first half of this book should serve as the major component of a classical one or two semester course in the calculus of variations and optimal control theory The second half of the book will describe the current research of the authors which is directed to solving these problems numerically In particular we present new reformulations of constrained problems which leads to unconstrained problems in the calculus of variations and new general accurate and efficient numerical methods to solve the reformulated problems We believe that these new methods will allow the reader to solve important problems

**Optimization and Approximation** Pablo Pedregal, 2017-09-07 This book provides a basic initial resource introducing science and engineering students to the field of optimization It covers three main areas mathematical programming calculus of variations and optimal control highlighting the ideas and concepts and offering insights into the importance of optimality conditions in each area It also systematically presents affordable approximation methods Exercises at various levels have been included to support the learning process

**Lectures on the Calculus of Variations and Optimal Control Theory** L. C. Young, **Introduction to the Calculus of Variations and**

**Control with Modern Applications** John A. Burns, 2013-08-28 Introduction to the Calculus of Variations and Control with Modern Applications provides the fundamental background required to develop rigorous necessary conditions that are the starting points for theoretical and numerical approaches to modern variational calculus and control problems The book also presents some classical sufficient conditions a

*Optimal Control and the Calculus of Variations* , 1993-03-18 Optimal Control is a modern development of the calculus of variations and classical optimization theory For this reason this introduction to the theory of Optimal Control starts by considering the problem of minimizing a function of many variables It moves from there via an exposition of the calculus of variations to the main subject which is the optimal control of systems governed by ordinary differential equations This approach should enable the student to see the essential unity of the three important areas of mathematics and also allow Optimal Control and the Pontryagin Maximum Principle to be placed in a proper context A good knowledge of analysis algebra and methods similar to that of a diligent British undergraduate at the start of the final year is assumed All the theorems are carefully proved and there are many worked examples and exercises for the student Although this book is written for the undergraduate mathematician engineers and scientists with a taste for

mathematics will find it a useful text *Electric Machines* Dionysios Aliprantis,Oleg Wasynczuk,2022-08-11 Offering a new perspective this textbook demystifies the operation of electric machines by providing an integrated understanding of electromagnetic fields electric circuits numerical analysis and computer programming It presents fundamental concepts in a rigorous manner emphasising underlying physical modelling assumptions and limitations and provides detailed explanations of how to implement the finite element method to explore these concepts using Python It includes explanations of the conversion of concepts into algorithms and algorithms into code and examples building in complexity from simple linear motion electromagnets to rotating machines Over 100 theoretical and computational end of chapter exercises test understanding with solutions for instructors and downloadable Python code available online Ideal for graduates and senior undergraduates studying electric machines electric machine design and control and power electronic converters and power systems engineering this textbook is also a solid reference for engineers interested in understanding analysing and designing electric motors generators and transformers *Control Systems* Jitendra R. Raol,Ramakalyan Ayyagari,2019-07-12 Control Systems Classical Modern and AI Based Approaches provides a broad and comprehensive study of the principles

mathematics and applications for those studying basic control in mechanical electrical aerospace and other engineering disciplines The text builds a strong mathematical foundation of control theory of linear nonlinear optimal model predictive robust digital and adaptive control systems and it addresses applications in several emerging areas such as aircraft electro mechanical and some nonengineering systems DC motor control steel beam thickness control drum boiler motional control system chemical reactor head disk assembly pitch control of an aircraft yaw damper control helicopter control and tidal power control Decentralized control game theoretic control and control of hybrid systems are discussed Also control systems based on artificial neural networks fuzzy logic and genetic algorithms termed as AI based systems are studied and analyzed with applications such as auto landing aircraft industrial process control active suspension system fuzzy gain scheduling PID control and adaptive neuro control Numerical coverage with MATLAB is integrated and numerous examples and exercises are included for each chapter Associated MATLAB code will be made available

### **Introduction To The Calculus of**

**Variations And Its Applications** Frederic Wan,2017-10-19 This comprehensive text provides all information necessary for an introductory course on the calculus of variations and optimal control theory Following a thorough discussion of the basic problem including sufficient conditions for optimality the theory and techniques are extended to problems with a free end point a free boundary auxiliary and inequality constraints leading to a study of optimal control theory

### **Lectures on the**

**Calculus of Variations and Optimal Control Theory** L. C. Young,2024-10-30 This book is divided into two parts The first addresses the simpler variational problems in parametric and nonparametric form The second covers extensions to optimal control theory The author opens with the study of three classical problems whose solutions led to the theory of calculus of variations They are the problem of geodesics the brachistochrone and the minimal surface of revolution He gives a detailed

discussion of the Hamilton Jacobi theory both in the parametric and nonparametric forms This leads to the development of sufficiency theories describing properties of minimizing extremal arcs Next the author addresses existence theorems He first develops Hilbert s basic existence theorem for parametric problems and studies some of its consequences Finally he develops the theory of generalized curves and automatic existence theorems In the second part of the book the author discusses optimal control problems He notes that originally these problems were formulated as problems of Lagrange and Mayer in terms of differential constraints In the control formulation these constraints are expressed in a more convenient form in terms of control functions After pointing out the new phenomenon that may arise namely the lack of controllability the author develops the maximum principle and illustrates this principle by standard examples that show the switching phenomena that may occur He extends the theory of geodesic coverings to optimal control problems Finally he extends the problem to generalized optimal control problems and obtains the corresponding existence theorems Calculus of Variations and Optimal Control Theory Magnus R. Hestenes, 1969

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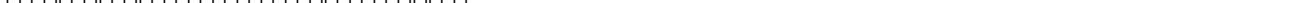
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