

# **An Introduction to Mathematical Optimal Control Theory Version 0.2**

By

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# An Introduction To Mathematical Optimal Control Theory

**Michael Athans, Peter L. Falb**



## **An Introduction To Mathematical Optimal Control Theory:**

**Optimal Control Theory** Donald E. Kirk, 2012-04-26 Upper level undergraduate text introduces aspects of optimal control theory dynamic programming Pontryagin's minimum principle and numerical techniques for trajectory optimization Numerous figures tables Solution guide available upon request 1970 edition [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 *An Introduction to Optimal Control Theory* Aaron Strauss, 2012-12-06 This paper is intended for the beginner It is not a state of the art paper for research workers in the field of control theory Its purpose is to introduce the reader to some of the problems and results in control theory to illustrate the application of these results and to provide a guide for his further reading on this subject I have tried to motivate the results with examples especially with one canonical simple example described in 3 Many results such as the maximum principle have long and difficult proofs I have omitted these proofs In general I have included only the proofs which are either 1 not too difficult or 2 fairly enlightening as to the nature of the result I have however usually attempted to draw the strongest conclusion from a given proof For example many existing proofs in control theory for compact targets and uniqueness of solutions also hold for closed targets and non uniqueness Finally at the end of each section I have given references to generalizations and origins of the results discussed in that section I make no claim of completeness in the references however as I have often been content merely to refer the reader either to an exposition or to a paper which has an extensive bibliography IV These 1ecture notes are revisions of notes I used for a series of nine 1ectures on control theory at the International Summer School on Mathematical Systems and Economics held in Varenna Italy June 1967 **Optimal Control** Leslie M. Hocking, 1991 Systems that evolve with time occur frequently in nature and modelling the behaviour of

such systems provides an important application of mathematics. These systems can be completely deterministic but it may be possible too to control their behaviour by intervention through controls. The theory of optimal control is concerned with determining such controls which at minimum cost either direct the system along a given trajectory or enable it to reach a given point in its state space. This textbook is a straightforward introduction to the theory of optimal control with an emphasis on presenting many different applications. Professor Hocking has taken pains to ensure that the theory is developed to display the main themes of the arguments but without using sophisticated mathematical tools. Problems in this setting can arise across a wide range of subjects and there are illustrative examples of systems from as diverse fields as dynamics, economics, population control and medicine. Throughout there are many worked examples and numerous exercises with solutions are provided.

*Mathematical Control Theory* Jerzy Zabczyk, 1992. This book is designed as a graduate text on the mathematical theory of deterministic control. It covers a remarkable number of topics. The book includes material on the realization of both linear and nonlinear systems, impulsive control and positive linear systems, subjects not usually covered in an introductory book. To get so much material in such a short space the pace of the presentation is brisk. However the exposition is excellent and the book is a joy to read. A novel one semester course covering both linear and nonlinear systems could be given. The book is an excellent one for introducing a mathematician to control theory. The book presents a large amount of material very well and its use is highly recommended.

*Bulletin of the AMS* *Mathematical Control Theory: An Introduction* presents in a mathematically precise manner a unified introduction to deterministic control theory. With the exception of a few more advanced concepts required for the final part of the book, this presentation requires only a knowledge of basic facts from linear algebra, differential equations and calculus. In addition to classical concepts and ideas, the author covers the stabilization of nonlinear systems using topological methods, realization theory for nonlinear systems, impulsive control and positive systems, the control of rigid bodies, the stabilization of infinite dimensional systems and the solution of minimum energy problems. The book will be ideal for a beginning graduate course in mathematical control theory or for self study by professionals needing a complete picture of the mathematical theory that underlies the applications of control theory.

*Introduction to Mathematical Control Theory* Stephen Barnett, S. Barnett, 1975. *Optimal Control* Michael Athans, Peter L. Falb, 2013-04-26. Geared toward advanced undergraduate and graduate engineering students, this text introduces the theory and applications of optimal control. It serves as a bridge to the technical literature, enabling students to evaluate the implications of theoretical control work and to judge the merits of papers on the subject. Rather than presenting an exhaustive treatise, *Optimal Control* offers a detailed introduction that fosters careful thinking and disciplined intuition. It develops the basic mathematical background with a coherent formulation of the control problem and discussions of the necessary conditions for optimality based on the maximum principle of Pontryagin. In depth examinations cover applications of the theory to minimum time, minimum fuel and to quadratic criteria problems. The structure, properties and engineering

realizations of several optimal feedback control systems also receive attention. Special features include numerous specific problems carried through to engineering realization in block diagram form. The text treats almost all current examples of control problems that permit analytic solutions and its unified approach makes frequent use of geometric ideas to encourage students' intuition.

**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.

*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.

*Optimal Control Theory* Suresh P. Sethi, 2022-01-03. This new 4th edition offers an introduction to optimal control theory and its diverse applications in management science and economics. It introduces students to the concept of the maximum principle in continuous as well as discrete time by combining dynamic programming and Kuhn-Tucker theory. While some mathematical background is needed, the emphasis of the book is not on mathematical rigor but on modeling realistic situations encountered in business and economics. It applies optimal control theory to the functional areas of management, including finance, production, and marketing, as well as the economics of growth and of natural resources. In addition, it features material on stochastic Nash and Stackelberg differential games and an adverse

selection model in the principal agent framework Exercises are included in each chapter while the answers to selected exercises help deepen readers understanding of the material covered Also included are appendices of supplementary material on the solution of differential equations the calculus of variations and its ties to the maximum principle and special topics including the Kalman filter certainty equivalence singular control a global saddle point theorem Sethi Skiba points and distributed parameter systems Optimal control methods are used to determine optimal ways to control a dynamic system The theoretical work in this field serves as the foundation for the book in which the author applies it to business management problems developed from his own research and classroom instruction The new edition has been refined and updated making it a valuable resource for graduate courses on applied optimal control theory but also for financial and industrial engineers economists and operational researchers interested in applying dynamic optimization in their fields

### **Optimal Control**

**Theory** L.D. Berkovitz, 2013-03-14 This book is an introduction to the mathematical theory of optimal control of processes governed by ordinary differential equations It is intended for students and professionals in mathematics and in areas of application who want a broad yet relatively deep concise and coherent introduction to the subject and to its relationship with applications In order to accommodate a range of mathematical interests and backgrounds among readers the material is arranged so that the more advanced mathematical sections can be omitted without loss of continuity For readers primarily interested in applications a recommended minimum course consists of Chapter I the sections of Chapters II III and IV so recommended in the introductory sections of those chapters and all of Chapter V The introductory section of each chapter should further guide the individual reader toward material that is of interest to him A reader who has had a good course in advanced calculus should be able to understand the definitions and statements of the theorems and should be able to follow a substantial portion of the mathematical development The entire book can be read by someone familiar with the basic aspects of Lebesgue integration and functional analysis For the reader who wishes to find out more about applications we recommend references 2 13 33 35 and 50 of the Bibliography at the end of the book

*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 **An**

**Introduction to Optimal Control Theory** Onésimo Hernández-Lerma, Leonardo R. Laura-Guarachi, Saul Mendoza-Palacios, David González-Sánchez, 2023-02-21 This book introduces optimal control problems for large families of deterministic and stochastic systems with discrete or continuous time parameter These families include most of the systems studied in many disciplines including Economics Engineering Operations Research and Management Science among many others The main objective is to give a concise systematic and reasonably self contained presentation of some key topics in optimal control theory To this end most of the analyses are based on the dynamic programming DP technique This technique is applicable to almost all control problems that appear in theory and applications They include for instance finite and infinite horizon control problems in which the underlying dynamic system follows either a deterministic or stochastic difference or differential equation In the infinite horizon case it also uses DP to study undiscounted problems such as the ergodic or long run average cost After a general introduction to control problems the book covers the topic dividing into four parts with different dynamical systems control of discrete time deterministic systems discrete time stochastic systems ordinary differential equations and finally a general continuous time MCP with applications for stochastic differential equations The first and second part should be accessible to undergraduate students with some knowledge of elementary calculus linear algebra and some concepts from probability theory random variables expectations and so forth Whereas the third and fourth part would be appropriate for advanced undergraduates or graduate students who have a working knowledge of mathematical analysis derivatives integrals and stochastic processes **Nonlinear Optimal Control Theory** Leonard David

Berkovitz, Negash G. Medhin, 2012-08-25 Nonlinear Optimal Control Theory presents a deep wide ranging introduction to the mathematical theory of the optimal control of processes governed by ordinary differential equations and certain types of differential equations with memory Many examples illustrate the mathematical issues that need to be addressed when using optimal control techniques in diverse areas Drawing on classroom tested material from Purdue University and North Carolina State University the book gives a unified account of bounded state problems governed by ordinary integrodifferential and delay systems It also discusses Hamilton Jacobi theory By providing a sufficient and rigorous treatment of finite dimensional control problems the book equips readers with the foundation to deal with other types of control problems such as those governed by stochastic differential equations partial differential equations and differential games **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 Primer on Optimal Control Theory Jason L. Speyer, David H. Jacobson, 2010-01-01 The performance of a process for example how an aircraft consumes fuel can be enhanced when the most effective controls and operating points for the process are determined This holds true for many physical economic biomedical manufacturing and engineering processes whose behavior can often be influenced by altering certain parameters or controls to optimize some desired property or output **Mathematical Control Theory** John Baillieul, Jan C. Willems, 1999 This volume on mathematical control theory contains high quality articles covering the broad range of this field The internationally renowned authors provide an overview of many different aspects of control theory offering a historical perspective while bringing the reader up to the very forefront of current research

**Measurement, Instrumentation, and Sensors Handbook, Second Edition** John G. Webster, Halit Eren, 2014-01-29 The Second Edition of the bestselling Measurement Instrumentation and Sensors Handbook brings together all aspects of the design and implementation of measurement instrumentation and sensors Reflecting the current state of the art it describes the use of instruments and techniques for performing practical measurements in engineering physics chemistry and the life sciences and discusses processing systems automatic data acquisition reduction and analysis operation characteristics accuracy errors calibrations and the incorporation of standards for control purposes Organized according to measurement problem the Spatial Mechanical Thermal and Radiation Measurement volume of the Second Edition Contains contributions from field experts new chapters and updates to all 96 existing chapters Covers instrumentation and measurement concepts spatial and mechanical variables displacement acoustics flow and spot velocity radiation wireless sensors and instrumentation and control and human factors A concise and useful reference for engineers scientists academic faculty students designers managers and industry professionals involved in instrumentation and measurement research and development Measurement Instrumentation and Sensors Handbook Second Edition Spatial Mechanical Thermal and Radiation Measurement provides readers with a greater understanding of advanced applications Measurement,

Instrumentation, and Sensors Handbook John G. Webster, Halit Eren, 2017-12-19 The Second Edition of the bestselling Measurement Instrumentation and Sensors Handbook brings together all aspects of the design and implementation of measurement instrumentation and sensors Reflecting the current state of the art it describes the use of instruments and techniques for performing practical measurements in engineering physics chemistry and the life sciences and discusses processing systems automatic data acquisition reduction and analysis operation characteristics accuracy errors calibrations and the incorporation of standards for control purposes Organized according to measurement problem the Spatial Mechanical Thermal and Radiation Measurement volume of the Second Edition Contains contributions from field experts new chapters and updates to all 96 existing chapters Covers instrumentation and measurement concepts spatial and mechanical variables displacement acoustics flow and spot velocity radiation wireless sensors and instrumentation and control and human factors A concise and useful reference for engineers scientists academic faculty students designers managers and industry professionals involved in instrumentation and measurement research and development Measurement Instrumentation and Sensors Handbook Second Edition Spatial Mechanical Thermal and Radiation Measurement provides readers with a greater understanding of advanced applications **The Calculus of Variations and Optimal Control**

George Leitmann, 2013-06-29 When the Tyrian princess Dido landed on the North African shore of the Mediterranean sea she was welcomed by a local chieftain He offered her all the land that she could enclose between the shoreline and a rope of knotted cowhide While the legend does not tell us we may assume that Princess Dido arrived at the correct solution by stretching the rope into the shape of a circular arc and thereby maximized the area of the land upon which she was to found Carthage This story of the founding of Carthage is apocryphal Nonetheless it is probably the first account of a problem of the kind that inspired an entire mathematical discipline the calculus of variations and its extensions such as the theory of optimal control 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 however those most useful to me have been the books of Oskar Bolza and of George M Ewing Part II is devoted to the elementary aspects of the modern extension of the calculus of variations the theory of optimal control of dynamical systems

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this example illustrates the forming of a three dimensional shape by a deep drawing process in general the forming procedure involves a forming step followed by a springback that occurs after the blank is removed from the tool the goal of analyzing the forming procedure is to determine the final deformed shape after springback

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