



# Optimal Control of Partial Differential Equations Theory, Methods and Applications

**Fredi Tröltzsch**

Graduate Studies  
in Mathematics  
Volume 112



American Mathematical Society

# Partial Differential Control Theory

**J. F. Pommaret**



## **Partial Differential Control Theory:**

**Partial Differential Control Theory** J. F. Pommaret, 2001      **Partial Differential Control Theory** J. F.

Pommaret, 2001 Algebraic analysis that is the algebraic study of systems of partial differential equations by means of module theory and homological algebra was pioneered around 1970 by M Kashiwara B Malgrange and V P Palamodov The theory of differential modules namely modules over a noncommutative ring of differential operators is a fashionable subject of research today However despite its fundamental importance in mathematics it can only be found in specialist books and papers and has only been applied in control theory since 1990 This book provides an account of algebraic analysis and its application to control systems defined by partial differential equations The first volume presents the mathematical tools needed from both commutative algebra homological algebra differential geometry and differential algebra The second volume applies these new methods in order to study the structural and input output properties of both linear and nonlinear control systems Hundreds of explicit examples allow the reader to gain insight and experience in these topics      Trends in

Control Theory and Partial Differential Equations Fatiha Alabau-Boussouira, Fabio Ancona, Alessio Porretta, Carlo Sinistrari, 2019-07-04 This book presents cutting edge contributions in the areas of control theory and partial differential equations Over the decades control theory has had deep and fruitful interactions with the theory of partial differential equations PDEs Well known examples are the study of the generalized solutions of Hamilton Jacobi Bellman equations arising in deterministic and stochastic optimal control and the development of modern analytical tools to study the controllability of infinite dimensional systems governed by PDEs In the present volume leading experts provide an up to date overview of the connections between these two vast fields of mathematics Topics addressed include regularity of the value function associated to finite dimensional control systems controllability and observability for PDEs and asymptotic analysis of multiagent systems The book will be of interest for both researchers and graduate students working in these areas

**Control Theory for Partial Differential Equations** Irena Lasiecka, 2000      **Control Theory of Systems Governed by Partial Differential Equations** A.K. Aziz, J.W. Wingate, M.J. Balas, 2014-05-10 Control Theory of Systems Governed by Partial Differential Equations covers the proceedings of the 1976 Conference by the same title held at the Naval Surface Weapons Center Silver Spring Maryland The purpose of this conference is to examine the control theory of partial differential equations and its application This text is divided into five chapters that primarily focus on tutorial lecture series on the theory of optimal control of distributed systems It describes the many manifestations of the theory and its applications appearing in the other chapters This work also presents the principles of the duality and asymptotic methods in control theory including the variational principle for the heat equation A chapter highlights systems that are not of the linear quadratic type This chapter also explores the control of free surfaces and the geometrical control variables The last chapter provides a summary of the features and applications of the numerical approximation of problems of optimal control This book will prove useful to

mathematicians engineers and researchers

### **Control Theory of Partial Differential Equations** Guenter

Leugering, 2017-08-09 The field of control theory in PDEs has broadened considerably as more realistic models have been introduced and investigated This book presents a broad range of recent developments new discoveries and mathematical tools in the field The authors discuss topics such as elasticity thermo elasticity aero elasticity interactions between fluids and elastic structures and fluid dynamics and the new challenges that they present Other control theoretic problems include parabolic systems dynamical Lamé systems linear and nonlinear hyperbolic equations and pseudo differential operators on a manifold This is a valuable tool authored by international specialists in the field

### **Mathematical Control Theory for Stochastic Partial Differential Equations** Qi Lü, Xu Zhang, 2021-09-17

This is the first book to systematically present control theory for stochastic distributed parameter systems a comparatively new branch of mathematical control theory The new phenomena and difficulties arising in the study of controllability and optimal control problems for this type of system are explained in detail Interestingly enough one has to develop new mathematical tools to solve some problems in this field such as the global Carleman estimate for stochastic partial differential equations and the stochastic transposition method for backward stochastic evolution equations In a certain sense the stochastic distributed parameter control system is the most general control system in the context of classical physics Accordingly studying this field may also yield valuable insights into quantum control systems A basic grasp of functional analysis partial differential equations and control theory for deterministic systems is the only prerequisite for reading this book

### **Control Theory for Partial Differential Equations**

Irena Lasiecka, Roberto Triggiani, 2013-08-13 First of a two volume treatise on deterministic control systems modeled by multi dimensional partial differential equations originally published in 2000

### **Partial Differential Control Theory** J.F.

Pommaret, 2014-11-28 The mathematical theory of open dynamical systems is a creation of the twentieth century Its humble beginnings focused on ideas of Laplace transforms applied to linear problems of automatic control and to the analysis and synthesis of electrical circuits However during the second half of the century it flowered into a field based on an array of sophisticated mathematical concepts and techniques from algebra nonlinear analysis and differential geometry The central notion is that of a dynamical system that exchanges matter energy or information with its surroundings i e an open dynamical system The mathematization of this notion evolved considerably over the years The early development centered around the input output point of view and led to important results particularly in controller design Thinking about open systems as a black box that accepts stimuli and produces responses has had a wide influence also in areas outside engineering for example in biology psychology and economics In the early 1960 s especially through the work of Kalman input state output models came in vogue This model class accommodates very nicely the internal initial conditions that are essentially always present in a dynamical system The introduction of input state output models led to a tempestuous development that made systems and control into a mature discipline with a wide range of concepts results algorithms and applications

### **Control**

## **Theory for Partial Differential Equations: Volume 2, Abstract Hyperbolic-Like Systems Over a Finite Time Horizon**

Irena Lasiecka, Roberto Triggiani, 2014-02-20 Second of a two volume treatise on deterministic control systems modeled by multi dimensional partial differential equations *Partial Differential Control Theory* J.-F. Pommaret, 2014-12-04 The mathematical theory of open dynamical systems is a creation of the twentieth century Its humble beginnings focused on ideas of Laplace transforms applied to linear problems of automatic control and to the analysis and synthesis of electrical circuits However during the second half of the century it flowered into a field based on an array of sophisticated mathematical concepts and techniques from algebra nonlinear analysis and differential geometry The central notion is that of a dynamical system that exchanges matter energy or information with its surroundings i e an open dynamical system The mathematization of this notion evolved considerably over the years The early development centered around the input output point of view and led to important results particularly in controller design Thinking about open systems as a black box that accepts stimuli and produces responses has had a wide influence also in areas outside engineering for example in biology psychology and economics In the early 1960 s especially through the work of Kalman input state output models came in vogue This model class accommodates very nicely the internal initial conditions that are essentially always present in a dynamical system The introduction of input state output models led to a tempestuous development that made systems and control into a mature discipline with a wide range of concepts results algorithms and applications **Control Theory for Partial**

**Differential Equations: Volume 1, Abstract Parabolic Systems** Irena Lasiecka, Roberto Triggiani, 2000-02-13 Originally published in 2000 this is the first volume of a comprehensive two volume treatment of quadratic optimal control theory for partial differential equations over a finite or infinite time horizon and related differential integral and algebraic Riccati equations Both continuous theory and numerical approximation theory are included The authors use an abstract space operator theoretic approach which is based on semigroups methods and which is unifying across a few basic classes of evolution The various abstract frameworks are motivated by and ultimately directed to partial differential equations with boundary point control Volume 1 includes the abstract parabolic theory for the finite and infinite cases and corresponding PDE illustrations as well as various abstract hyperbolic settings in the finite case It presents numerous fascinating results These volumes will appeal to graduate students and researchers in pure and applied mathematics and theoretical engineering with an interest in optimal control problems *Control Theory for Partial Differential Equations: Volume 2,*

*Abstract Hyperbolic-like Systems Over a Finite Time Horizon* Irena Lasiecka, Roberto Triggiani, 2000-02-13 Originally published in 2000 this is the second volume of a comprehensive two volume treatment of quadratic optimal control theory for partial differential equations over a finite or infinite time horizon and related differential integral and algebraic Riccati equations Both continuous theory and numerical approximation theory are included The authors use an abstract space operator theoretic approach which is based on semigroups methods and which unifies across a few basic classes of evolution

The various abstract frameworks are motivated by and ultimately directed to partial differential equations with boundary point control Volume 2 is focused on the optimal control problem over a finite time interval for hyperbolic dynamical systems A few abstract models are considered each motivated by a particular canonical hyperbolic dynamics It presents numerous fascinating results These volumes will appeal to graduate students and researchers in pure and applied mathematics and theoretical engineering with an interest in optimal control problems

*Optimal Control of Systems Governed by Partial Differential Equations* Jacques-Louis Lions, 1971

**Control Theory and Partial Differential Equations**, 1983 This document describes research activity supported under this grant from its inception June 1982 to the present KR

**Optimal Control of Partial Differential Equations** Fredi Tröltzsch, 2024-03-21 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

**Mathematical Control of Coupled PDEs** Irena Lasiecka, 2002-01-01

**Partial Differential Equations and Group Theory** J.F. Pommaret, 2013-03-09 Ordinary differential control theory the classical theory studies input output relations defined by systems of ordinary differential equations ODE The various concepts that can be introduced controllability observability invertibility etc must be tested on formal objects matrices vector fields etc by means of formal operations multiplication bracket rank etc but without appealing to the explicit integration search for trajectories etc of the given ODE Many partial results have been recently unified by means of new formal methods coming from differential geometry and differential algebra However certain problems

invariance equivalence linearization etc naturally lead to systems of partial differential equations PDE More generally partial differential control theory studies input output relations defined by systems of PDE mechanics thermodynamics hydrodynamics plasma physics robotics etc One of the aims of this book is to extend the preceding concepts to this new situation where of course functional analysis and or a dynamical system approach cannot be used A link will be exhibited between this domain of applied mathematics and the famous Backlund problem existing in the study of solitary waves or solitons In particular we shall show how the methods of differential elimination presented here will allow us to determine compatibility conditions on input and or output as a better understanding of the foundations of control theory At the same time we shall unify differential geometry and differential algebra in a new framework called differential algebraic geometry

*partial differential equation methods in control and shape analysis* Giuseppe Da Prato, 1997-02-20 Based on the International Federation for Information Processing WG 7.2 Conference held recently in Pisa Italy Provides recent results as well as entirely new material on control theory and shape analysis Written by leading authorities from various disciplines

Estimation and Control Problems for Stochastic Partial Differential Equations Pavel S. Knopov, Olena N. Deriyeva, 2013-09-17 Focusing on research surrounding aspects of insufficiently studied problems of estimation and optimal control of random fields this book exposes some important aspects of those fields for systems modeled by stochastic partial differential equations It contains many results of interest to specialists in both the theory of random fields and optimal control theory who use modern mathematical tools for resolving specific applied problems and presents research that has not previously been covered More generally this book is intended for scientists graduate and post graduates specializing in probability theory and mathematical statistics The models presented describe many processes in turbulence theory fluid mechanics hydrology astronomy and meteorology and are widely used in pattern recognition theory and parameter identification of stochastic systems Therefore this book may also be useful to applied mathematicians who use probability and statistical methods in the selection of useful signals subject to noise hypothesis distinguishing distributed parameter systems optimal control and more Material presented in this monograph can be used for education courses on the estimation and control theory of random fields

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