
Preface

Control theory has developed rapidly since the first papers by Pontryagin and collaborators in the late 1950s, and is now established as an important area of applied mathematics. Optimal control and optimization theory have already found their way into many areas of modeling and control in engineering, and nowadays are strongly utilized in many other fields of applied sciences, in particular biology, medicine, economics, and finance. Research activity in optimal control is seen as a source of many useful and flexible tools, such as for optimal therapies (in medicine) and strategies (in economics). The methods of optimal control theory are drawn from a varied spectrum of mathematical results, and, on the other hand, control problems provide a rich source of deep mathematical problems. The choice of applications to either life sciences or economics takes into account modern trends of treating economic problems in osmosis with biological paradigms.

A balance of theory and applications, the text features concrete examples of modeling real-world problems from biology, medicine, and economics, illustrating the power of control theory in these fields.

The aim of this book is to provide a guided tour of methods in optimal control and related computational methods for ODE and PDE models, following the entire pathway from mathematical models of real systems up to computer programs for numerical simulation. There is no pretense of being complete; the authors have chosen to avoid as much as possible technicalities that may hide the conceptual structure of the selected applications. A further important feature of the book is in the approach of “learning by doing.” The primary intention of this book has been to familiarize the reader with basic results and methods of optimal control theory (Pontryagin’s maximum principle and the gradient methods); it provides an elementary presentation of advanced concepts from the mathematical theory of optimal control, which are necessary in order to tackle significant and realistic problems. Proofs are produced whenever they may serve as a guide to the introduction of new concepts and methods in the framework of specific applications, otherwise explicit references to the existing literature are provided. “Working examples”

are conceived to help the reader bridge those introductory examples fully developed in the text to topics of current research. They may stimulate Master's and even PhD theses projects.

The computer programs are developed and presented in MATLAB[®] which is a product of The MathWorks, Inc. This is a very flexible and simple programming tool for beginners, but it can also be used as a high-level one. The numerical routines and the GUI (Graphical Users Interface) are quite helpful for programming. Starting with simple programs for simple models we progress to difficult programs for complicated models. The construction of every program is carefully presented. The numerical algorithms presented here have a solid mathematical basis. One of the main goals is to lead the reader from mathematical results to subsequent MATLAB programs and corresponding numerical tests.

The volume is intended mainly as a textbook for Master's and graduate courses in the areas of mathematics, physics, engineering, computer science, biology, biotechnology, and economics. It can also aid active scientists in the above areas whenever they need to deal with optimal control problems and related computational methods for ODE and PDE models.

Chapter 1 is devoted to learning several MATLAB features by examples. A simple model from economics is presented in Section 1.1.1, and models from biology may be found in Sections 1.5 and 1.7. Chapter 2 deals with optimal control problems governed by ordinary differential equations. By Pontryagin's principle more information about the structure of optimal control is obtained. Computer programs based on mathematical results are presented. Chapter 3 is devoted to numerical approximation by the gradient method. Here we learn to calculate the gradient of the cost functional and to write a corresponding program. Chapter 4 concerns age-structured population dynamics and related optimal harvesting problems. Chapter 5 deals with some optimal control problems governed by partial differential equations of reaction-diffusion type. The last two chapters connect theory with scientific research.

Basic concepts and results from functional analysis and ordinary differential equations including Runge-Kutta methods are provided in appendices.

Matlab codes, Errata and Addenda can be found at the publisher's website: <http://www.birkhauser-science.com/978-0-8176-8097-8>.

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Sciences and Economics
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