BOOK REVIEW

Lyapunov-Based Control of Mechanical Systems

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This book presents recent developments in the area of nonlinear control for mechanical systems, as well as some of the necessary background, at an introductory level.
A main distinction is made between rigid mechanical systems (modeled by ordinary differential equations) and flexible mechanical systems (modeled by partial differential equations).

Three chapters are devoted to the first type of systems. They include nonlinear systems of motion, involving position, velocity and acceleration as state variables. The problem is to design a controller that makes the position converge to a desired trajectory.

Other three chapters develop the second type of systems. In this case, boundary conditions appear. The control techniques that are presented are active boundary control strategies.

The central concept of this book is the Lyapunov design. That is, the use of energy-related functions V(t) that prove stability of the considered closed-loop systems. The selection of a good V(t) function depends on the closed-loop system's particular structure and, nonetheless, on good understanding of the physical insight and on experience.

Chapter 1 is an introduction to the topics of the book. Two simple examples are meant to illustrate some of the typical problems that one might encounter in controlling rigid or flexible mechanical systems.

In a survey-like style, **Chapter 2** presents "Control Techniques for Friction Compensation." The nonlinear friction model incorporates viscous, Coulomb, static, and Stribeck friction-related effects. The models used are reduced-order or full-order single-input single-output models. Several adaptive control techniques are analyzed in detail and their effects on the various friction parameters are compared for an experimental setup.

In **Chapter 3**, "Full-State Feedback Tracking Controllers," the considered models are nonlinear, multi-input multi-output, rigid mechanical systems with parametric uncertainty. A commonly used simplifying assumption is that the dynamics are linearly dependent on the parameter vector. Three adaptive controllers (standard, desired trajectory-based, and modular) are presented and stability results are derived by means of Lyapunov functions.

Chapter 4, "Output Feedback Tracking Controllers," concludes the part on rigid mechanical systems by addressing the problem of position tracking without having knowledge of the exact velocity over time. This approach is useful because the lack of velocity sensors implies minimizing the cost of experiments. Several methods are proposed: an observer/controller (the observer part estimates the velocities and the controller part drives the position and velocity tracking errors to zero); a linear filter-based adaptive controller (the filter is used to generate a velocity tracking error signal; only a semiglobal stability result is obtained with this model); a nonlinear filter-based adaptive controller (a global stability result is then obtained).

In **Chapter 5**, "Strings and Cables," the study of systems governed by partial differential equations with boundary conditions begins. The interesting and simple examples of modeling vibrating strings or mechanical systems with cable-induced vibrations are based on the wave equation. The boundary control strategies developed for this type of systems are of two classes: model-based controllers and adaptive controllers.

Chapter 6 is called "Cantilevered Beams" and it presents two of the important existing models for cantilevered flexible beam, Euler-Bernoulli and Timoshenko models. In both cases, model-based and adaptive control laws are derived, and interesting experimental and simulation results are used for comparison.

Chapter 7 presents three "Boundary Control Applications": axially moving string system, flexible link robot arm, and flexible rotor system. The aim of a controller for these engineering applications is to reduce vibrations. The last two applications are hybrid, because they are formed of both rigid and flexible subsystems.

Specially designed experiments for the control techniques are complementing the theoretical control developments presented in this book. The experiments were carried out using two environments developed at Clemson University (WinMotor and Qmotor), that control in real-time various electro-mechanical systems. Some control programs in the C programming language are listed in an appendix. Other numerical results are obtained using computer simulations.

It is worth noticing that all chapters provide a thorough image on every particular type of models and controllers that are presented. Nevertheless, the models that are chosen are rather generic, so that many other types of mechanical systems can benefit from these studies.

Some of the characteristics of this book are: a rigorous exposition style, a clear and intuitive explanation of the mechanical phenomena, alternating with detailed mathematics in the theorem/proof parts. An appendix presents some mathematical background in the form of definitions and lemmas.

Other special feature is the presentation of both ordinary and partial differential equations-based mechanical systems in the unified framework of Lyapunov analysis.

This book can be considered a textbook on advanced nonlinear controllers for mechanical systems, but also, a reference book. Its audience should be composed of researchers, professionals and graduate students in the areas of systems, control, and robotics.

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