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BOOK REVIEW

ADAPTIVE APPROXIMATION BASED CONTROL: UNIFYING NEURAL, FUZZY AND TRADITIONAL ADAPTIVE APPROXIMATION APPROACHES. Jay A. Farrell and Marios M. Polycarpou, Wiley, New York, 2006. No of pages: 440. ISBN 978-0-471-72788-0

Since the 1990s there have been significant developments in the control of highly uncertain, nonlinear dynamical systems and there has been a tremendous amount of activities in neural control and adaptive fuzzy control approaches [1–4]. These methods include intelligent control, neural control, adaptive fuzzy control, memory-based control, knowledge-based control, adaptive nonlinear control, and adaptive linear control, to name a few. Although these methods have different names with different perspectives, there is a common objective among them that the practitioners are to design a controller that is guaranteed to be stable and achieve a high level of control performance for systems with poorly modelled nonlinear effects or with changing dynamics during operation. To this aim, it is very desirable to develop approaches within a unifying framework. The book by Farrell and Polycarpou presents adaptive function estimation and feedback control methodologies that develop and use approximations to portions of the nonlinear functions describing the system dynamics while the system is in online operation. It examines some fundamental control problems in a systematic manner. The book starts with an explicit description of function approximation and nonlinear control system. For function approximation, several conventional function approximators are introduced in detail. For nonlinear control systems, various control problems are stated. These problems include linearization, backstepping control, robust control, adaptive control, etc. With these preliminary knowledge explicitly described, the book proceeds to address adaptive approximation-based control for scalar nonlinear systems and higher-order nonlinear systems. Analysis tools are also provided for performance assessment of existing control systems with uncertainty. More specifically, the book is organized into the following eight chapters.

Chapter 1 provides introduction to the book. A brief discussion on the problem of adaptive approximation-based control methods which unifies the typical adaptive fuzzy and neural control approaches and the state-of-the-art in addressing the problem is given.

Chapters 2–4 investigate the fundamental aspects of adaptive approximation-based control which include approximation theory, its structures, and parameter estimation methods. All these preliminary knowledge will be referenced throughout the remainder of the book.

Chapter 2 introduces approximation theory with a motivating example around which a few important issues are discussed. Generally speaking, function approximation can be divided into offline and online approximations. An understanding of offline function approximation is necessary before delving into online approximation. In particular, this chapter motivates why various issues should (or should not) be taken into account when selecting an appropriate approximator for a particular application.

Chapter 3 discusses several neural, fuzzy, and traditional approximation structures in a unifying framework based on linear and nonlinear models of parameters to be determined. The function approximators include polynomials, splines, radial basis functions, cerebellar model articulation controller, multilayer perceptron, fuzzy approximation, and wavelets. The motivation and properties of each function approximators are illustrated with a detailed example.

Chapter 4 is devoted to parameter estimation methods, including the formulation of parametric models for the approximation problem, the design of online learning schemes, and the derivation of parameter estimation algorithms with certain stability and robustness properties, for adaptive function approximation in a continuous-time dynamical system. The methods will provide a foundation for the adaptive approximation-based control approaches to be developed in Chapters 5–7. Several examples are worked out to show the detailed procedure of parameter estimation methods.

Chapters 5–7 cover nonlinear control systems where Chapter 5 addresses some of the dominant methods that have been developed for nonlinear control design such as small-signal linearization, feedback linearization, backstepping, robust nonlinear control design methods and adaptive nonlinear control. It sets the foundation for the use of adaptive approximation to improve the performance of nonlinear controller operation in the presence of nonlinear model uncertainties to be discussed in Chapters 6 and 7. The main focus of Chapter 5 is on tracking control problem and the regulation problem of systems with the full state being measured. For each method, one illustrative example is given.

Chapter 6 brings together different topics in Chapters 2–5 in the synthesis and analysis of adaptive approximation-based control systems with the focus on scalar systems with unknown nonlinearities. A general framework for modelling of dynamical systems, design of feedback control systems, and evaluation and testing of the overall, closed-loop system is presented. Stabilization of scalar systems is discussed with nonlinearities being both known and unknown. Several other aspects of the adaptive approximation-based control problem such as the effects on closed-loop performance of the learning rate, feedback gain, and initial conditions as well as tracking problem, and stability and robustness properties of the closed-loop system are also studied.

Chapter 7 considers adaptive approximation-based control for higher-order dynamical systems and provides a rigorous stability analysis of the resulting closed-loop system in parallel to Chapter 6. The design and analysis of adaptive approximation-based control in this chapter is applied to two general classes of nonlinear systems with unknown nonlinearities. One is the class of feedback linearizable systems; the other is the class of triangular nonlinear systems that allow the use of the backstepping control design procedure.

Chapter 8 presents detailed design and analysis of adaptive approximation-based controller applied to a benchmark problem: fixed-wing aircraft.

The book is very well written. The topics chosen are all fundamental control problems and are treated in depth. The primary objective of this book is to present the methods systematically in a unifying framework called adaptive approximation-based control which unifies neural control, adaptive fuzzy control, learning control, and approximation-based control, facilitate discussion of underlying properties and comparison of alternative techniques. Without doubt this book represents a significant contribution to the important research topic of analysis and design for control systems with uncertainties. Results included in the book, along with an extensive bibliography will prove to be an important resource for researchers in this area as well as researchers interested in entering this area. The adaptive approximation-based control approaches in the book will prove equally valuable to practicing engineers with different backgrounds and can be viewed as one of the available tools that a control designer should have in her/his control toolbox. Although the mathematics involved in the book is on the heavy side, all the analysis and design algorithms are explicit. All the results are illustrated with fully worked out examples and/or simulation.

This book is particularly a good text for a graduate or advanced undergraduate course. Short courses or training courses for control engineers to gain knowledge in approximation-based control would be another avenue for this book.

REFERENCES

1. Bhatnagar S, Kumar S. A simultaneous perturbation stochastic approximation-based actor-critic algorithm for Markov decision processes. *IEEE Transactions on Automatic Control* 2004; **49**:592–598.
2. Mekki H, Chtourou M, Derbel N. Stochastic approximation based adaptive neural control for a class of nonlinear systems. *Control and Intelligent Systems* 2005; **33**:190–198.
3. Skafidas E, Fradkov A, Evans RJ, Mareels IMY. Trajectory-approximation-based adaptive control for nonlinear systems under matching conditions. *Automatica* 1998; **34**:287–299.
4. Song Q, Spall JC, Soh YC. Robust neural network tracking controller using simultaneous perturbation stochastic approximation. *Forty-second IEEE Conference on Decision and Control*, Maui, HI, 2003; 6194–6199.

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