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Book reviews

Neural networks for modeling and control of dynamic systems: a practitioner's handbook

M. Nørgaard, O. Ravn, N.K. Poulsen, and L.K. Hansen; Springer, London, 2000, 246pp., paperback, ISBN 1-85233-227-1

This book from Springer joins several other books (cf., e.g., Hrycej, 1997; Miller, Sutton, & Werbos, 1990; Tolle & Ersue, 1992) published a few years back on the subject of neurocontrol. The subject of neural networks for modeling and control of dynamical systems represents an important area of applications of artificial neural networks that reemerged in 1980s. On the other hand, to control engineers, neurocontrol, or neural networks for controls, brings about some new and fresh ideas to the modeling and control design for nonlinear dynamical systems. The approach based on neural networks is generally viewed as an important milestone in identification and adaptive control of nonlinear dynamical systems.

Neural Networks for Modeling and Control of Dynamic Systems deals with control problems of unknown nonlinear dynamical systems using neural networks. One of the chapters (Chapter 2) deals with system identification of nonlinear dynamical systems using neural networks. The next two chapters (Chapters 3 and 4) deal with the control of nonlinear dynamical systems using neural networks and several case studies. With an introductory chapter at the beginning, the book has only four chapters.

Chapter 1 introduces the background information about neural networks. In particular, it introduces in detail the feedforward neural network structure, which is termed as multilayer perceptron networks in this book. The book is extended from a Ph.D. thesis done by the first author of the book. It is thus not a surprise that the book does not cover various neural network structures studied in the literature. The main object used in the book in terms of neural networks is the two-layer feedforward neural networks with sigmoidal type activation function for the hidden layer and linear function for the output layer. Other popular structures used often by control engineers such as radial basis function networks and recurrent neural networks are not mentioned at all since they are not required in the book later on.

Chapter 2 provides details about how to use neural networks (i.e., feedforward neural networks or multilayer perceptron networks) for the purpose of nonlinear system identification. It covers model structure selection, data collection, neural network training (weight determination), and validation of the training. It presents a very clear picture for the purpose of nonlinear system modeling and identification using neural networks. To this reviewer, the whole chapter seems to be a very good summary of what is published and known in the literature on the subject of nonlinear system identification using neural networks. It is noted that the dynamical systems studied in this chapter as well as in the book are discrete-time systems.

Chapter 3 is about neural network-based control design which constitutes the main ingredient of this book. Similar to the case in the classical adaptive control, it includes direct and indirect approaches. The former is the case where a neural network controller is obtained without going through the phase of systems identification and it thus is also called direct inverse control. The latter will unavoidably involve a phase for system identification to obtain a model of the nonlinear unknown dynamical system using a neural network. A neural network-based controller is then designed based on the model established. Topics in this chapter include internal model control, feedforward control, optimal control, control based on feedback linearization and predictive control. To this reviewer, this chapter covers a very comprehensive list of topics in various aspects of nonlinear control system design.

Chapter 4 concludes this book with four interesting case studies. The four case studies are: (1) sunspot prediction, (2) hydraulic actuator modeling, (3) pneumatic servo control, and (4) water level control in a conic tank. Some of them are very challenging nonlinear control problems.

The book covers the main subject well, though without vigorous proof for many statements made in the book. This is in direct contrast to classical control texts where every statement made is usually accompanied by vigorous mathematics. This book is particularly good for self-study by practicing engineers who have some control background. It can also be used as a graduate or advanced undergraduate reference text. It is particularly useful for courses with project/laboratory sessions. Short courses or training courses for control engineers to gain knowledge in neural networks for controls would be another avenue for this book. In addition, the book can be treated as a handbook for practicing engineers working in the field of neural networks for control applications. This book may not be good for general classroom use due to its limited coverage on neural network structures. Some additional benefits to the book are the software packages developed by the authors available at http://www.iau.dtu.dk/nnspringer.html. The web site contains the software, manuals, exercise problems and more.

One thing that bothers this reviewer is about the comments in the preface. The authors state that "it is important to pursue methods that yield good performance in practice and thus there is generally little concern with the possibility for proving stability" with which this reviewer cannot agree. In my view, in order for neurocontrol technique to gain wide acceptance in practice and in real world applications, stability proof is a fundamental requirement. Otherwise, there will always be people concerned about the safety aspects of the approach in cases such as airplane autopilot. Without a concrete theoretical guarantee for stability, neurocontrol approach would never be considered for applications such as airplane autopilot (excluding toy airplanes). The book lacks mathematical and statistical foundation for the neural network-based methods will be viewed as a negative side of the book.

In my opinion, the book treats neural networks as a tool for modeling nonlinear dynamical system and a tool for solving nonlinear control problems, in a way similar to classical adaptive control in the linear case. Some recent and new developments in the areas of neural networks for controls have been exploring the use for neural networks in approximating optimal control (e.g., dynamic programming) for nonlinear dynamical systems. Interested readers are referred to Neural Dynamic Optimization (Seong & Widrow, 2001a,b,c) and Neurodynamic Programming (Si & Wang, 2001) (see also the book by Bertsekas and Tsitsiklis (1996) and earlier work under Adaptive Critic Designs (Prokhorov & Wunsch, 1997)).

References

Bertsekas, D. P., & Tsitsiklis, J. N. (1996). *Neuro-dynamic programming*. Belmont, MA: Athena Scientific.

Hrycej, T. (1997). *Neurocontrol: Towards an industrial control methodology*. New York: Wiley.

Miller, III, W. T., Sutton, R. S., & Werbos, P. J. (Eds.). (1990). *Neural networks for control*. Cambridge, MA: The MIT Press.

Prokhorov, D. V., & Wunsch, D. C. (1997). Adaptive critic designs. *IEEE Transactions on Neural Networks*, *8*, 997–1007.

Seong, C.-Y., & Widrow, B. (2001a). Neural dynamic optimization for control systems—Part I: Background. *IEEE Transactions on Systems, Man, and Cybernetics—Part B: Cybernetics*, *31*, 482–489.

Seong, C.-Y., & Widrow, B. (2001b). Neural dynamic optimization for control systems—Part II: Theory. *IEEE Transactions on Systems, Man, and Cybernetics—Part B: Cybernetics*, *31*, 490–501.

Seong, C.-Y., & Widrow, B. (2001c). Neural dynamic optimization for control systems—Part III: Applications. *IEEE Transactions on Systems, Man, and Cybernetics—Part B: Cybernetics*, *31*, 502–513.

Si, J., & Wang, Y.-T. (2001). On-line learning control by association and reinforcement. *IEEE Transactions on Neural Networks*, *12*, 264–276.

Tolle, H., & Ersue, E. (1992). *Neurocontrol: Learning control systems inspired by neuronal architectures and human problem solving strategies*. New York: Springer.

Derong Liu
Department of Electrical and Computer Engineering,
University of Illinois at Chicago,
Chicago, IL 60607, USA
E-mail address: dliu@ieee.org

About the reviewer

Derong Liu received the Ph.D. degree in electrical engineering from the University of Notre Dame in 1994. From 1993 to 1995, he was with General Motors R&D Center, Warren, Michigan. From 1995 to 1999, he was an assistant professor in the Department of Electrical and Computer Engineering, Stevens Institute of Technology, Hoboken, New Jersey. He joined the University of Illinois at Chicago in 1999 as an assistant professor of electrical and computer engineering. He is coauthor (with A.N. Michel) of the books Qualitative Analysis and Synthesis of Recurrent Neural Networks (New York: Marcel Dekker, 2002) and Dynamical Systems with Saturation Nonlinearities: Analysis and Design (New York: Springer, 1994). Dr. Liu was recipient of Michael J. Birck Fellowship from the University of Notre Dame (1990); he was recipient of Harvey N. Davis Distinguished Teaching Award from Stevens Institute of Technology (1997); and he was recipient of Faculty Early Career Development (CAREER) award from the National Science Foundation (1999).

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Stochastic controls—Hamiltonian systems and HJB equations

Jiongmin Yong and Xun Yu Zhou; Springer, New York, Inc., 1999, ISBN 0-387-98723-1.

It is often the case that a physical system can be controlled through the intervention of human being. If the system is under the influence of some uncertain factors, then it is a random (stochastic) control system. Controlled stochastic differential equations are useful in the mathematical modeling of such systems.

If the law of evolution of a physical system can be mathematically modeled by some controlled stochastic differential equations, then it is certainly the most important task to construct such equations. This construction of the mathematical model is one of the main objectives of the so-called *system identification*. There have been enormous research on this topic.

Once the mathematical model has been constructed for a practical controlled system, the next step is to make most profit out of this model. One wishes to adequately control (or intervene) the system so as to achieve the maximum profit or to minimize the cost in favor of the controller. This is the objective of optimal control. When the system is under the influence of some uncertainties, it is called *stochastic optimal control.*

The mathematical problem of stochastic optimal control dealt within this book contains a system of controlled stochastic differential equations describing the evolution of the physical system and a performance criterion function. The stochastic differential equations considered are driven by standard Brownian motion with drift and diffusion