Book Review

Stable Adaptive Neural Network Control—S. S. Ge, C. C. Hang, T. H. Lee, and T. Zhang (Boston, MA: Kluwer, 2001) *Reviewed by Frank L. Lewis*

I. Introduction

In [1], Kuhn showed that the stage at which a new scientific theory becomes a generally accepted paradigm is marked by the publication of the first textbooks. This occurred in our field after World War II, when books by Evans, Chestnut and Mayer, Brown and Campbell, and others marked the acceptance of linear frequency domain techniques in control system design. In the 1960s, the first texts on state–space design appeared.

For many years, neural networks had been relegated with other techniques of unproven consistency or based on intuitive biological or decision-making design techniques under the disguise of "intelligent control systems." General acceptance within the control systems community and industry for these schemes was not forthcoming due to the lack of repeatable design algorithms, formal mathematical stability proofs, and firm performance guarantees. Fairly recently, it has been shown by several research groups that neural network control systems are the next logical step in the development of adaptive control systems to more general unknown plants, including those that cannot be linearly parameterized in terms of unknown system parameters. Stability proofs have been provided, showing how to choose both the topology of neural network controllers and the weight training algorithms for guaranteed performance. Now, neural networks have taken the place they deserve within the historical and developmental context of advanced adaptive control systems.

Textbooks that have recently appeared as neural network control enters the accepted paradigm stage of its development are [2]–[5], as well as the book being reviewed here. Also very important in the development of nonparametric approximation-based control is [4].

II. The Book

The first chapters of *Stable Adaptive Neural Network Control* present introductory mathematical preliminaries. It is interesting to see there some concepts not usually associated with neural network control theory, including the Mean-Value Theorem and the Implicit Function Theorem.

Chapter 3 presents background on neural networks, both linear-in-the-parameter networks and multilayer nonlinear-in-the-parameter networks. Approximation properties and some standard tuning algorithms are discussed. Chapter 4 derives neural network controllers for single-input–single-output systems in Brunovsky Canonical Form and affine in the control input. After a formal stability proof, it is refreshing to see rigorous results on the transient behavior of these control systems. These can be of help in selecting the controller design parameters. Transient behavior of neural network controllers is traditionally not dealt with in the literature.

The lengthy Chapter 5 presents the heart of the book. Here, a novel family of integral Lyapunov functions is used to avoid the control singularity problem in feedback linearization-based designs, and to design neural network controllers with global stability. Backstepping design is used to confront controller design for strict-feedback nonlinear systems (affine in the controls). The controllers are extended to the case where bounds on unknown functions are not known.

In Chapter 6, controllers are designed for nonaffine nonlinear systems. Feedback linearization requires unknown diffeomorphisms. Using the Implicit Function Theorem, one determines a nonlinear controller whose unknown functions can be estimated using neural networks. When all the states are not known, an output-feedback neural network controller is designed that uses an observer. An interesting application is given to a continuously stirred tank reactor. In Chapter 7, backstepping is used to provide neural network controllers for systems in triangular form, both strict-feedback affine and pure-feedback nonaffine systems.

III. Conclusion

This book is well and thoughtfully laid out, and represents the culmination of years of rigorous and insightful research. It is in a form suitable for a graduate course in control systems. Industry engineers will find advanced nonparametric adaptive controllers of several sorts that are directly designed to confront problems of plant structure and uncertainty that normally fall outside the capabilities of traditional adaptive controllers.

References

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