

Preface

Contemporary man-made engineering systems or systems associated with socioeconomical or biological processes can be particularly complex, characterized by possibly unknown nonlinearities, operating in uncertain environments. The complexity of these systems hinders the design of suitable control techniques, because the dynamical mathematical model required by “conventional” control approaches is unknown most of the times. Even in the case that the mathematical description is possible, there exist difficulties in the adaptation of the feedback controllers when the system is time varying with an unknown to the designer way. These drawbacks have led the recent research effort to “intelligent” techniques, seeking the development of new approximation models and control techniques that have the ability to learn and adapt to varying environmental conditions or internal dynamical behavior of the system.

Artificial neural networks and adaptive fuzzy systems constitute a reliable choice for modeling unknown systems, since they can be considered as universal approximators. In this sense, they can approximate any smooth nonlinear function to any prescribed accuracy in a convex compact region, provided that sufficient hidden neurons and training data or fuzzy rules are available. Recently, the combination of artificial neural networks and adaptive fuzzy systems has led to the creation of new approaches, fuzzy-neural, or *neuro-fuzzy* approaches that capture the advantages of both fuzzy logic and neural networks and intend to approach systems in a more successful way. Another modeling approach, that stems from fuzzy cognitive maps, is the creation of a *cognitive graph* capturing the causal relationships between the crucial variables of the system associated with the node values of the graph. Numerous applications and recent theoretical developments have shown that, under proper training, this model is capable of approximating the behavior of complex nonlinear systems in the engineering field and beyond.

This book is based on recent developments of the theory of Neuro-Fuzzy and the Fuzzy Cognitive Network (FCN) models and their potential applications. Its primary purpose is to present a set of alternative approaches, which would allow the design of:

- potent neuro-fuzzy system approximators and controllers able to guarantee stability, convergence, and robustness for dynamical systems with unknown nonlinearities
- appropriate cognitive graph modeling with guaranteed operational convergence and parameter identification algorithms.

The book is the outcome of the recent research efforts of its authors. Its is divided into two parts, each one being associated with each of these models. Part I is devoted to the Neuro-Fuzzy approach. It is based on the development of a new adaptive recurrent neuro-fuzzy approximation scheme, which is used for system identification and the construction of a number of controllers with guaranteed stability and robustness. The central idea in the development of the new approximation scheme is an alternative description of a classical dynamical fuzzy system, which allows its approximation by high-order neural networks (HONNs), a point that constitutes an innovative element of the presented scheme. The capabilities of the developed approximators and controllers are tested on a number of simulated benchmark problems and a real DC motor system.

Part II of the book is devoted to the FCN model. Fuzzy Cognitive Networks stem from fuzzy cognitive maps (FCM), initially introduced by Bart Kosko in 1986. An FCN is actually an operational extension of FCM which assumes, first, that it always reaches equilibrium points during its operation and second, it is in continuous interaction with the system it describes and may be used to control it. This way, the FCN is capable of capturing steady-state operational conditions of the system it describes and associates them with input values and appropriate weight sets. In the sequence, it stores the acquired knowledge in fuzzy rule-based databases, which can be used in determining subsequent control actions. Part II presents basic theoretical results related to the existence and uniqueness of equilibrium points in FCN, the adaptive weight estimation based on system operation data, the fuzzy rule storage mechanism, and the use of the entire framework to control unknown plants. The operation of the FCN framework is simulated and tested on a number of selected applications, ranging from a well-known benchmark problem to real-life potential projects, like hydroelectric power plant coordination and a novel scheme for optimal operation of a small-scale smart electric grid of renewable power plants based on real meteorological data. Through these examples, various aspects of the application of the FCN framework of operation are revealed.

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Yiannis Boutalis
Dimitrios Theodoridis
Theodore Kottas
Manolis A. Christodoulou

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Boutalis, Y.; Theodoridis, D.; Kottas, T.; Christodoulou,
M.A.

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