Preface

Our motivation when enroling this project was to cover the lack of a book where most of the fuzzy modeling and control techniques, frequently used by European research groups, could be put together. Moreover, some chapters have been added in order to illustrate the application of these techniques in several scenarios. The book was elaborated by members of the CEA-IFAC Intelligent Control Group and the EUSFLAT Working Group on Fuzzy Control. Both associations include among their members some of the most well-recognized experts in the fuzzy control field in Spain and Europe, respectively.

The book covers the range from systems modeling to controllers design and an interesting set of applications, being divided into the following three parts. Part I is dedicated to describe fuzzy modeling techniques. It is important to note that in most of the chapters Takagi-Sugeno (TS) model is used instead of Mamdani one, which is a clear demonstration of how this modeling technique has been spread for the last decades in the fuzzy control area. Three chapters deal with this topic. Chapter 1 describes new approaches to improve the local and global approximation and modeling capability of TS fuzzy model, solving traditional identification problems when membership functions are overlapped by pairs, something very popular in industrial control applications. Chapter 2 shows the application of extended Kalman filter for the parametric adaptation of a TS fuzzy model, which can be implemented online based on input/output data with high accuracy and in a computationally efficient manner. Chapter 3 presents a systematic technique to reduce the number of rules and so the complexity of TS fuzzy systems, by using Functional Principal Components Analysis. It is shown that the main problem which arises, the lack of rules interpretability, is not a problem in predictive control applications.

Part II is dedicated to the parameters adjustment of fuzzy systems. Chapter 4 presents a formal design methodology for the synthesis of fuzzy control systems which guarantees the stability of the closed-loop system, without requiring to search for Lyapunov functions. Chapter 5 extends the well-known *sector nonlinearity* of TS fuzzy modeling methodology to the polynomial framework. While the major part of existent results in the literature do not pay attention to the validity

region of the obtained solution, here the problem is addressed presenting a methodology to estimate the domain of attraction. Chapter 6 is concerned with the introduction of a Fault Tolerant Control framework using uncertain TS fuzzy models. The design is performed using a Linear Matrix Inequality-based synthesis that directly takes into account the TS description of the system and its uncertainties. Chapter 7 is focused on the use of learning and gradient-free optimization techniques for optimal tuning of fuzzy and neuro-fuzzy systems. Single feedback control and internal model control schemes are considered in the two proposed strategies. Chapter 8 presents aspects concerning the tuning of simple TS PI-like fuzzy controllers by adaptive evolutionary optimization algorithms, which are built by using Gravitational Search Algorithm and Charged System Search algorithm structures.

Finally, Part III is dedicated to show a variety of fuzzy control applications. Chapter 9 deals with vibrations as a very common problem which appears in many engineering applications. In order to reduce (or ultimately eliminate) their potential negative impact, special attention is paid to semi-active dampers. Their main advantage is the ability to modify its structural parameters requiring less amount of power. Chapter 10 presents a general neuro-fuzzy model for the fast ferry vertical motion. Intelligent controllers using fuzzy logic are proposed to stabilize the vertical motion of the craft and therefore to improve the comfort and safety of sailing. Chapter 11 shows the application of soft computing techniques to control road vehicles. AUTOPÍA project combines different artificial intelligent techniques: fuzzy logic allows modeling the behavior of the planning, cooperation, and decision agents according to the human way of doing; evolutionary algorithms allow to adjust the agent behavior to optimize the operation or cost criteria; and swarm algorithms allow modeling the emergent behavior of the urban traffic flow. Chapter 12 proposes the use of a fuzzy logic controller to drive an electrolyzer in an experimental hybrid renewable energy system. The controller is able to deal with the interactions of the various system components and the energy flow, providing a stable and reliable source of energy. Chapter 13 describes a new design methodology for automatic synthesis of fuzzy logic-based inference systems on programmable logic devices and Application-Specific Integrated Circuits (ASIC). It describes both an efficient architecture for hardware implementation and a set of design tools that allow accelerating the exploration of the design space of fuzzy inference modules. Chapter 14 presents a TS fuzzy control system developed for the throttle and brake pedals of a car, whose objective is to follow another one which precedes it, while maintaining a safe distance depending on the speed. A genetic algorithm and a mathematical model are used for the tuning of the parameters in the consequents of the rules.

We hope you enjoy this book as much as we did coordinating its elaboration.

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