CONTROL OF NONLINEAR AND HYBRID PROCESS SYSTEMS, Panagiotis D. Christofides and Nael H. El-Farra, Springer, New York, NY, 2005

Most industrial processes have nonlinear and hybrid components, and controlling them with linear controllers based on approximate linear models often results in suboptimal operation as the process drifts away from the nominal conditions used for model development and control system design. *Control of Nonlinear and Hybrid Process Systems* by Christofides and El-Farra presents a general methodology and practical techniques for designing nonlinear feedback control systems for more effective control of nonlinear and hybrid processes. Control system design methods proposed by the authors are based on Lyapunov techniques. The authors have used many important chemical process models such as non-isothermal continuous stirred tank reactors (CSTR), isothermal batch crystallizers, fluidized catalytic cracker, reactor–separator systems, and biological networks to illustrate the performance and limitations of the controllers designed by using the methods that they developed. Model uncertainty, actuator constraints, time delays in measurement and actuator moves are accounted for in model development and controller design methods developed by the authors. Hybrid control has been integrated with fault-tolerant control. Framing the fault-tolerant control problem as discrete switching from one control system to another, the authors have leveraged the framework of hybrid control to design and assess fault-tolerance in chemical process operations.

The book combines the various journal papers published by the authors and El-Farra's doctoral dissertation and provides a valuable single source for their methods. The authors have made a successful effort to integrate many concepts and techniques to provide a seamless treatment of the subject matter, which enhances the value of the book. The book is intended for researchers, graduate students and control engineers. The book assumes a certain knowledge of linear system theory, Lyapunov methods, and introductory concepts in nonlinear systems, robust control, and optimization. The authors provide some background information, but readers interested in learning these topics or review them should find a graduate level linear systems and control theory book useful. Useful details are provided in the discussion of examples and case studies, and the proofs of theorems are put as appendices. Both of these decisions have enhanced the readability of the text.

The authors defined the objectives of the book as:

- Development of a unified framework for the design of nonlinear feedback control systems for processes modelled by nonlinear systems with uncertainty in variables and constraints on manipulated variables. The framework should provide an explicit characterization of the stability and performance properties of the controllers designed.
- Development of a hybrid nonlinear control methodology for nonlinear processes with switched, constrained, and uncertain dynamics. The methodology should integrate the design of lower-level nonlinear controllers and the design of higher-level supervisory switching logic.
- Providing a fundamental understanding of the control problem for nonlinear and hybrid processes, and the coupling of continuous dynamics and discrete events.
- Providing case studies to illustrate the application of the proposed controller design and analysis methods to chemical and biological processes, assess their effectiveness and limitations, and compare their performance to traditional control methods.

The book is organized into nine chapters and six appendices. Over 300 references are provided. Chapter 1 states the motivation for the book and provides several examples of nonlinear processes and hybrid processes. Chapter 2 summarizes some basic results on the analysis and control of nonlinear systems. Robust inverse optimal controller design for input/output linearizable nonlinear systems with time-varying bounded uncertain variables is introduced in Chapter 3. The combination of state-feedback controllers with high-gain observers and saturation filters enables the design of dynamic robust output-feedback controllers that enforce closed-loop stability and near-optimal performance. A case study with chemical reactors illustrates the implementation of the controllers for a system with uncertainties. Chapter 4 focuses on nonlinear multivariable processes with time-varying uncertain variables and manipulated variable constraints. A unified framework that integrates robustness and explicit constraint handling capabilities is presented. A general state-space Lyapunov-based approach is used to derive explicit formulas for bounded robust nonlinear feedback controllers with well-characterized performance and stability characteristics. By using high-gain observers along with the controllers, output-feedback controllers are obtained. The implementation of the controllers is illustrated and their performance is compared to traditional control strategies by using a case study with chemical reactors. A hybrid predictive control structure that unifies model predictive control (MPC) and bounded control for linear time-invariant systems with input constraints is introduced in Chapter 5. The MPC is embedded inside the stability region of the bounded controller which is used as a fall-back control system if the MPC is unable to stabilize the closed-loop system. Supervisory action switches from MPC to the bounded controller to guarantee closed-loop stability. Chapter 6 generalizes the hybrid predictive control strategy to the stabilization problem of nonlinear systems with uncertainties. Again, chemical reactor models are used to illustrate the methodology. Chapter 7 presents the development of hybrid nonlinear control methodologies for two classes of hybrid nonlinear processes. The first class includes processes with constrained dynamics and uncertainties that consist of a finite number of continuous nonlinear dynamic subsystems with hard constraints on manipulated variables. A supervisor initiates transitions between these subsystems. The proposed control methodology includes integrated synthesis *via* multiple Lyapunov functions of a family of robust bounded nonlinear feedback controllers and of upper-level switching laws used by the supervisor to initiate safe transitions between various modes of operation that guarantee robust stability of the overall system. The second class of switched processes has scheduled mode transitions, following a prescribed switching sequence. Lyapunov-based predictive controllers are designed for each mode of operation and transition constraints are incorporated in the predictive controller design to ensure stability of the switched closed-loop system. Chemical reactor control is used to illustrate the performance of these controllers. A biological network control problem is also presented; the application of the proposed hybrid system techniques to eukaryotic cell cycle regulation illustrates the usefulness of these techniques for analysing mode transitions in biological networks. Chapter 8 extends the hybrid control methodology to the design of fault-tolerant control systems for processes with distributed interconnected processing units. A hierarchical distributed architecture is developed, integrating lower-level feedback control of the individual processing units with a higher-level logic-based supervisory system. Cases studies with interconnected chemical reactors illustrate the efficacy of the proposed framework. Scalability to processes with larger number of processing units has not been addressed. Chapter 9 focuses on control of nonlinear systems with time delays described by nonlinear differential difference equation (DDE) systems. Small and large time delays are addressed, and nonlinear state observer design and output feedback control for DDE systems with state and measurement delay are presented. Case studies with a reactor–separator system with recycle and a fluidized-bed catalytic cracker illustrate the implementation of the methodology.

The authors provide an extensive list of references that are up-to-date. Some of the key references in nonlinear systems [1–3], hybrid systems [4], and fault-tolerant control [5–7] provide a good introduction to the techniques and challenges and offer an account of the historical progress. An alternative approach for hybrid control can be developed by multi-agent systems [8] and fault-tolerant control can be implemented by real-time knowledge-based systems [9].

The book is a good source for advanced control techniques for nonlinear and hybrid chemical process systems. It will be useful both as a professional reference and as a supplementary text in graduate level control courses.

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COMPUTATIONAL INTELLIGENCE IN TIME SERIES FORECASTING: THEORY AND ENGINEERING APPLICATIONS, A. K. Palit and D. Popovic, Springer, London, 2005, 362 pp, US $149, ISBN: 1852339489

THE BOOK TOPICS

The book deals with an emerging engineering discipline, *viz*, the *Computational Intelligence* that has rapidly found wide application in various branches of science and technology. The term Computational Intelligence is largely understood as a collection of intelligent computational methodologies, such as neuro-computing, fuzzy logic-based computing, and evolutionary computing that help in solving complex computational problems, not solvable or at least not easily solvable, using the conventional mathematical tools.

The research activity in combined application of different intelligent approaches to problem solving was initiated by Zadeh in 1994 [1] who has introduced the term *soft computing* with fuzzy logic, neuro-computing, and probabilistic reasoning as its principal constituents. Later, this term was extended to include the evolutionary computation and learning strategies. Also, the statistical version of evolutionary computation was developed relying on randomized global search paradigms suitable for finding the optimal solution of multi-dimensional problems. Thereafter, the basic search strategies have been widely extended and diversified to include the novel search strategies, such as *genetic algorithms*, *genetic programming*, *evolutionary strategies*, *evolutionary programming*, *differential evolution*, etc.

However, the most decisive step in formulating the term Computational Intelligence was made during the 1994 IEEE World Congress on Computational Intelligence (WCCI) [2]. At that time, R. J. Marks, in his Editorial Note to the IEEE Transactions on Neural Networks [3], pointed out that, although seeking similar goals, computational intelligence has emerged as a sovereign field distinct from artificial intelligence. Since that time the WCCI has become a regular event. In addition, in 2006, the IEEE Magazine on Computational Intelligence was launched.

During the last decade, Computational Intelligence approaches have again and again proved their efficiency in solving complex scientific and engineering problems that are not easily solvable using conventional computational methods. This spans signal processing, multisensor data fusion, pattern recognition, performance monitoring, fault diagnosis, etc. Since the majority of such problems are based on experimental observations and on collection of experimental data, mainly structured and analysed in the form of time series, the book under review is mainly focussed on time series analysis and forecasting of experimental data in engineering.

