

# **Preface: An Overview of the Contributions**

This book is a multi-authored monograph on advanced research in the field of complex dynamic network and dynamic systems involving both event-driven and time-driven evolution dynamics, and also some statistical mechanics, hence employing some kind of combined control and supervision. It does present a number of case studies and certain reflections in a broader prospective towards implementable system engineering creations along the lines of complex dynamic networks and systems. The book comprises five parts: 1. Control and supervision for complex networks and systems; 2. Machine intelligence and learning in complex control systems; 3. Control and supervision of complex mechanical and robotic structures; 4. Control and supervision in multi-agent and industrial systems; and 5. Novel ideas and variable-structure and switched systems control. This overview is presented consequently following the parts along with enumeration of chapters albeit individual chapters in the book are solely ordered accordingly, i.e., do not bear enumeration. However, the names of the authors of each chapter are included beneath the title of their respective contribution.

Initially, this collective monograph has emerged from the selected a set of selected contributions, but in expanded and revised versions, of a special international conference chaired by Prof. Mogens Blanke, one of the leaders of scientific research program COSY 1995–1999 of European Science Foundation (ESF), and also one of the editors of the 2001 book, *Control of Complex Systems*, by Springer. Several of the present contributing authors, including this editor, also participated in the ESF research program in complex systems control and wrote that monograph. Thus this book is an important step forward into both theoretical and technological issues of complex network and systems.

The main feature in common of the contributions authored in this book is a kind of highlighting certain existing synergies of control, computing, and communication in order to achieve a guaranteed stable and sustainable plant system operation with robust quality. In the individual chapters, there appear contributions that range from a generally applicable model-based diagnosis and systems engineering to medical, to communication, to power-grid and airport networks, to creating biological brains for control applications and safety-critical human–machine systems,

to process industries and industrial complexes, to biped robots, to large space structures and UAVs, to precision servomechanisms, as well as to other advanced mechatronics technologies. Nonetheless, most of the contributions introduce certain novel theoretical techniques for hard-to-control networks and systems, which go beyond standard decentralized feedback and where compound system architectures of control and supervision are employed. It is this sense present book may be viewed as a kind of follow-up monograph to those collective research efforts summarized in the 2001 monograph by Springer.

## **Part I Control and Supervision for Complex Networks and Systems**

### **Diagnosis for Control and Decision Support for Autonomous Vehicles Mogens Blanke, Søren Hansen, and Morten Rufus Blas**

In this chapter there are presented the theoretical foundations for design methodologies that now appear as enabling technology for a new area of system designs that are reliable in practice. Yet they are also affordable due to the use of fault-tolerant philosophies and tools that make engineering efforts minimal for their implementation. It also includes the examples for an autonomous aircraft and a baling system for agriculture to illustrate the generic design procedures and real-life results. It should be noted, diagnosis and, when possible, prognosis of faults are essential for safe and reliable operation. Developments of methodologies that cope with complex and nonlinear systems have considerably matured and methodology and associated tools have become available in the form of theory and software for design. Genuine industrial cases have also become available. Analysis of system topology, referred to as structural analysis, has proven to be unique and simple in use and a recent extension to *active structure* techniques have made fault isolation possible in a wide range of systems. Following residual generation using these topology-based methods, deterministic and statistical change detection has proven very useful for online prognosis and diagnosis. For complex systems, results from non-Gaussian detection theory have been employed with convincing results.

### **Integration of Supervisory Control Synthesis in Model-Based Systems Engineering**

**Jos C.M. Baeten, Joanna M. van de Mortel-Fronczak, and Jakobus E. Rooda**

This chapter discusses the integration of recently developed supervisor synthesis techniques and tools in engineering plant processes based on suitable models. Formal models play an important role here because they enable the use of various model-based analyses for early integration techniques, and tools. Engineering processes based on formal models are shown to be able to cope with complexity. They also support time-to-market and development costs reduction. Moreover, application of supervisory control synthesis in the development of control systems

can speed up the process considerably. The proposed approach is illustrated by examples of industrial cases, where supervisors synthesized have successfully been implemented and integrated in existing resource-control platforms.

### **Output Synchronization of Dynamical Networks Having Nodes with Relative-Degree-One Nonlinear Systems**

**Yanyan Liu, Georgi M. Dimirovski, and Jun Zhao**

This chapter studies the output synchronization problem in complex dynamic networks that have nonlinear dynamic systems with relative-degree-one at their nodes. System property of passivity has been found to be a useful tool for solving the output synchronization problem in such dynamic networks. Although not all dynamic systems may be passive, however, it is nonetheless shown still passivity can be successfully used to output synchronize dynamic networks. If a node nonlinear system is weakly minimum phase and has relative-degree-one, then it is shown to be feedback equivalent to a passive system. The feedback passivation result is exploited in order to investigate the output synchronization of dynamic networks. The conditions are found under which the output synchronization of dynamic networks, having node nonlinear systems with relative-degree-one, is achieved without the need the negative definiteness property of the outer coupling matrix.

### **Mechanism Design for Incentive Compatible Control of Networks**

**Anil Kumar Chorppath and Tansu Alpcan**

This chapter provides an overview of the recent results in the area of mechanisms and games for distributed control of networks and authors recent contributions. The methodology and algorithms developed are applied to diverse network control problems such as interference and spectrum management. The heterogeneous behavior of users, which ranges from altruistic to selfish and to malicious, is being modeled within the analytical framework of game theory. Network mechanism design aims to achieve system-level goals such as maximization of aggregate network performance using specific methods in networks, where users are strategic and selfish decision-makers with individual preferences. A mechanism design approach is adopted to quantify the effect of adversarial behavior, which ranges from extreme selfishness to destructive maliciousness. Differentiated pricing is proposed as a method to counter and mitigate adversarial behavior. An additional application to the location privacy in mobile commerce is also briefly discussed.

### **Building Smart Grid: Optimal Coordination of Consumption with Decentralized Energy Generation and Storage**

**Araz Ashouri, Sebastian Gaulocher, and Petr Korba**

This work describes a timely implementation of an office and/or personal smart grid for environmentally friendly buildings. These can be equipped with a local energy source (e.g., photovoltaic panels or combined heat-power units), energy storage devices (batteries, electric hot water boilers, heating and ventilation systems including air conditioning), a building energy management system with sensors

(e.g., providing the room temperatures), and household appliances acting as actuators (in general, split into groups of schedulable and non-schedulable ones). The idea behind this work is to develop an automatic control system which would optimally decide for the end-customer when to buy, sell, or store electric energy with the objective to minimize his total costs. At the same time, it fulfills all constraints in terms of the limits on power allowed to be taken from the grid. In this project, a model predictive control approach to the energy optimization problem in a building has been proposed based on utilization of a real-time pricing signal which reflects daily peaks in consumption to the energy management system. Different scenarios have been run and the results are discussed here.

### **Passivity-Based Switching Rule and Control Law Co-design of Networked-Switched Systems with Feedback Delays** **Dan Ma, and Georgi M. Dimirovski**

In this theoretical study, a class of switched linear systems under a hybrid state feedback controller with time-varying delays is studied. The main contribution is given on the issue of how to co-design switching rule and feedback control law so as to make the closed-loop system strictly input feed-forward output-feedback passive for all admissible time delays in the feedback channels. Sufficient conditions for strict input feed-forward, output-feedback ‘passivitation’ of switched systems with time-varying delays under some state-dependent switching rule by using the method of multiple storage functions is derived. The proposed switching rule can achieve strict input feed-forward, output-feedback passivity of the switched delay systems whose all subsystems can be input feed-forward output-feedback non-passive. The finite gain  $L_2$  stability in closed-loop is guaranteed. Furthermore, under the proposed switching rule, the asymptotic stability can be guaranteed if the switched system is zero-state detectable when exogenous disturbance input is zero.

## **Part II Machine Intelligence and Learning in Complex Control Systems**

### **Creating and Controlling Complex Biological Brains** **Kevin Warwick**

This chapter presents a closer look into how animal and/or human brain cells can be cultivated (grown) and given a robot physical body (as a controlling brain) in which they can move around and interact with the world. These observations are utilized to propose a design that is aimed at creating a specific kind of cyborg. This is realized as a new form of artificial intelligence in which the complexity of a highly nonlinear biological neural network is employed to uniquely control a real-world robot. An adequate presentation is given in which the communication/control

feedback loop is described and considered in terms of learning, performance, long-term operation, and specialization within the neural structure. Experimental results are presented and also an outline of certain open philosophical arguments is given.

### **Iterative Learning Control as an Enabler for Robotic-Assisted Upper Limb Stroke Rehabilitation**

**Eric Rogers, Chris T. Freeman, Ann-Marie Hughes, Jane H. BurrIDGE, Katie L. Meadmore, and Tim Excell**

In this chapter, a recent research is surveyed where iterative learning control, developed initially for robots executing commonly encountered industrial tasks such as sequentially collecting objects from one location and transferring them to another, is used to control the assistive stimulation in robotic-assisted upper limb stroke rehabilitation. The presentation is accompanied with a number of both analytical and empirical results obtained in the course of this research endeavor. The results given include the outcomes of small-scale clinical trials with stroke patients, and areas for future research are also briefly discussed. This research is aimed at coping with an increased burden on health care and rehabilitation resources due to the number of people suffering a stroke and therefore novel approaches to rehabilitation are required, if the capacity of health services is to meet future demands.

### **Adaptive Fuzzy Modeling Based Quantitative Assessment of Operator Functional State in Complex and Safety-Critical Human–Machine Systems**

**Jian-Hua Zhang and Ru-Bin Wang**

In this chapter the human operator functional state, OFS, is quantitatively estimated by using multiple sources of measured psycho-physiological data. In the data acquisition experiments, an automation-enhanced Cabin Air Management System (aCAMS) was employed to simulate with high fidelity a highly complex multitask platform of human–machine cooperative process control. Two types of adaptive fuzzy models, viz., adaptive-network-based fuzzy inference system and genetic algorithm based Mamdani fuzzy model, are constructed to estimate the temporal fluctuations of the OFS. The fuzzy models are used to reveal the complex unknown correlation between the psycho-physiological (i.e., electroencephalographic and cardiovascular) variables and the operator performance (i.e., primary-task-related performance). The adaptive fuzzy modeling paradigm was validated by using the data measured from a group of young healthy and well-trained male subjects (two trials for each), who were engaged in the manual control tasks under aCAMS experimental environment.

### **Space Independent Community Detection in Airport Networks**

**Emil Gegov, Maria Nadia Postorino, Alexander Gegov, and Boriana Vachova**

In this research contribution, the problem of community detection has been investigated within large networks with highly changeable but most often unpredictable flows. The given objects of exploration are the topology and passenger

flows of the United States Airport Network (USAN) over two decades. The network model consists of a time-series of six network snapshots for the years 1990, 2000, and 2010, which capture bimonthly passenger flows among US airports. The volume of these flows is naturally affected by spatial proximity, and therefore, a model (recently proposed in the literature) accounting for this phenomenon is used to identify the communities of airports that have particularly high flows among them, given their spatial separation. This research results highlight the fact that some general techniques from network theory, such as network modeling and analysis, can be successfully applied for the study of a wide range of complex systems; while others, such as community detection, need to be tailored for a specific system. Thus a successful empirical study on the complex systems in air transportation also involving network modeling and aimed at community detection problem has been accomplished.

### **Decentralized Control of Complex Dynamic Systems Employing Function Emulation by Neural Networks**

**Yuanwei Jing, Yanxin Zhang, Vesna M. Ojleska, Tatjana D. Kolemisevska, and Gerogi M. Dimirovski**

In this contribution, a novel robust adaptive control design synthesis is proposed for a class of mechatronic nonlinear systems possessing similarity property has been derived. The design employs both high-order neural networks and math-analytical results in a compatible way. This approach exploits adequate usage of the structural feature of composite similarity systems and of neural networks to solve the representation issue of uncertainty interconnections and subsystem gains by online updating the weights of the neural networks. Lyapunov stability theory and attraction domain analysis are used. The proposed design synthesis guarantees the practical real stability in closed-loop, but also requires skills to obtain larger attraction domains around the operating equilibrium. The benchmark example of elastically interconnected two inverted pendulums on carts, thus creating a complex nonlinear dynamic system possessing inherent uncertainties, is investigated and its decentralized control solved.

### **Neural Networks with Strong Anticipation and Some Problems of Complexity Theory**

**Oleksandr S. Makarenko**

This chapter presents the study of one new type of models of neural networks, which takes into account certain anticipation property. As the base model in it, Hopfield-type of models with anticipation has been explored. The basic new qualities discovered in this research is the possibility of multi-valued solutions of given neural networks. Different types of behavior of such systems have been explored depending on parameters of networks. The problems of complex solutions and stored information have been considered, including the measures of complexity in deterministic and non-deterministic cases. Presumable applications of such models for living and social systems are discussed within the context of these new type models of neural networks, which take into account property of anticipation.

As the base background model, the Hopfield-type models with anticipation are found to be crucial. Different types of behavior of such systems have been explored depending on parameters of networks.

## **Part III Control and Supervision of Complex Mechanical Structures and Robots**

### **How to Cope with Disturbances in Biped Locomotion?**

**Miomir Vukobratović, Branislav Borovac, Mirko Raković, and Milutin Nikolić**

Nowadays walking humanoid-like robots have become an expanding reality. Furthermore, it is expected that the humanoid robots of the near future will “live” and work in a common environment with humans. This imposes the requirement that their operational efficiency ought to be close to that of humans. The main prerequisite to achieve this is to ensure the robot’s efficient motion quality, that is, its ability to compensate for the ever-present disturbances. This work considers precisely the strategies of how to compensate for the disturbances of different intensities: small which are permanently present and large that jeopardize the robot’s dynamic balance instantly. It is illustrated that those two classes of disturbances require quite different compensation approaches.

### **New Adaptive Algorithm for Flexible Spacecraft Control**

**Vladislav Y. Rutkovsky, Victor M. Glumov, and Victor M. Sukhanov**

During the last couple of decades, the design, implementation, and deployment of orbit in space of large space structures have been expanded to unprecedented extent. All these large space structures are essentially flexible structures, which exhibit delicate dynamics even when motion on orbit is well settled. For the case of large space structure control, a new adaptation algorithm for system with reference model is proposed. Its operation does not depend on the intensity and spectral composition of the input actions and its realization does not require estimation of external disturbances. The proposed algorithm functioning is illustrated on the example of large space structure control. It is a new type of large-size spacecraft (space energy stations, large orbiting reflectors). Such an object cannot be inserted into orbit in assembled condition because of its big size. Therefore LSS is assembled in orbit and it is a discretely evolving structure. As the control object it is multi-frequency oscillating system with discretely time-varying parameters and number of freedom degrees. For the case of large space structure control, proposed algorithm is simplified; yet the designed control system performs high-precision operation.

### **State-Dependent Riccati Equation-Based Tracking Control of a Hydraulic Seismic Isolator Test Rig**

**Stefano Pagano, Ricardo Russo, Salvatore Strano, and Mario Terzzo**

A novel design and implementation of hydraulic seismic isolator test rig which employs a nonlinear optimal tracking control based on the state-dependent Riccati equation (SDRE) technique has been developed. It is aimed at testing the devise and systems which are used mitigate effects due to either earthquake or sever storm winds. Earthquake and wind storm effects can be mitigated by means of base isolation strategies. The base isolation is typically effected using passive, semi-active, or active systems. These devices must be tested in order to obtain the horizontal force-displacement cycle that allows for deducing analytical description of their dynamic characteristics if they are to be practically used. The SDRE algorithm fully preserves system nonlinearities, bringing the nonlinear system to a linear structure with state-dependent coefficient (SDC) matrices. The linear quadratic (LQ) synthesis method has been be applied to this state-dependent state-space equation characterized by the SDC matrices and improved control design achieved. A dSPACE DS1103 hardware has been employed for the control implementation and also for the real-time resolution of the SDRE, which supported by the obtained results from real-time experiments.

### **Multi-Robot Navigation Using Market-Based Optimization**

**Rainer Palm, Abdelbaki Bouguerra, and Muhammad Abdullah**

This contribution is dedicated to a thorough investigation of the artificial force potential fields for obstacle avoidance and their optimization by a market-based approach in scenarios where several robots are acting in a shared area. The potential field method has been enhanced by fuzzy logic, traffic rules, and the technique of market-based optimization (*MBa*). Fuzzy rules are used to deform repulsive potential fields in the vicinity of obstacles to produce smoother motions around them. Traffic rules are used to deal with situations where robots are crossing each other. The *MBa*, on the other hand, is used to strengthen or weaken repulsive potential fields generated due to the presence of other robots. For testing and verification, the navigation strategy is implemented and tested in simulation of more realistic vehicles. Extensive simulation experiments are performed to examine the improvement of the traditional potential field method by the *MBa* strategy and verify the performance achieved.

### **Fault-Tolerant Estimation of UAV Dynamics via Robust Kalman Filter**

**Chingiz Hajiyeu and Halil Ersin Soken**

This contributed chapter presents a novel robust adaptive algorithm for estimating sensor and actuator faults in unmanned aerial vehicles (UAV). A covariance scaling based robust adaptive Kalman filter (RAKF) algorithm has been developed for the case of sensor/actuator faults. The proposed RAKF uses variable scale factors for scaling the process and measurement noise covariances and eliminating the effect of the faults on the estimation procedure. First the existing covariance estimation



based adaptation techniques are reviewed. After choosing the efficient adaptation method, an overall concept for the RAKF is proposed. In this concept, the filter initially isolates the fault, either in the sensors or actuators, and then it applies the required adaptation process such that the estimation characteristic is not deteriorated. The performance of the proposed filters is investigated via simulations for the UAV state estimation problem.

### **Guidance Laws and Navigation Systems for Quadrotor UAV: Theoretical and Practical Findings**

**Stojce Deskovski, Vasko Sazdovski, and Zoran Gacovski**

This chapter presents a novel contribution towards the design of small-size, inexpensive, quadrotor-based unmanned aerial vehicle (UAV). Nowadays UAVs are becoming essential for many applications where human presence is considered unnecessary, dangerous, or impossible. These applications include variety of scientific, civilian, and military applications. This paper reflects the efforts that we are taking over the years toward a deeper understanding of these technologies. A presentation of a low-cost, small-size quadrotor UAV that we have modified for our experiments is given. Both practical and theoretical research activities in the guidance navigation and control algorithms for quadrotor UAVs are discussed here. These analytical, simulation, and experimental studies have yielded certain novel findings, which are reported in this contribution.

## **Part IV Control and Supervision in Multi-Agent and Industrial Systems**

### **Distributed Supervisory Strategies for Multi-Agent Networked Systems**

**Allesandro Casavola, Emanuel Garone, and Francesco Tedesco**

In this chapter, certain novel distributed supervisory strategies for multi-agent linear systems that are connected via data networks and subject to coordination constraints are presented. Such a *coordination-by-constraint* paradigm is based on the online management of the prescribed set points and it is characterized by a set of spatially distributed dynamic systems, connected via communication channels, with possibly dynamical coupling among them which need to be supervised and coordinated in order to accomplish their overall objective. Two distributed strategies will be fully described and analyzed. First, a “sequential” distributed strategy is presented where only one agent per decision time is allowed to manipulate its own reference signal. Such a strategy is then instrumental to introduce a more effective “parallel” distributed strategy, in which all agents are allowed to modify their own reference signals simultaneously under certain conditions.

**Petri Net-Based Synthesis of Agent Cooperation by Means of Modularity and Supervision Principles****František Čapkovič**

This chapter presents an exploration study on the possibility and the means how the principles of modularity and of supervision can be utilized in the synthesis of the cooperation among a collective of agents. Subsystems modeling agents of different kinds are understood to be modules of discrete-event systems (DES). They are modeled by means of place/transition Petri nets (P/T PN). A desired strategy of the mutual behavior of agents during their cooperation is expressed by conditions for the DES-based supervisor synthesis. Then, the synthesized supervisor does obtrude the cooperation strategy on the agents at the realization of a common job. The supervisor synthesis is realized either by means of the P/T PN place invariants (P-invariants) or by the virtually extended method, where P-invariants are complemented by conditions imposed on P/T PN transitions and/or on the Parikh's vector, especially in order to express priorities.

**Adaptive Internal Model-Based Distributed Output Agreement in a Class of Multi-Agent Dynamic Systems****Esma Gül and Veysel Gazi**

This contribution presents a novel study of the agreement problem in a class of multi-agent dynamic systems that have uncertainties. In particular, the case of the distributed output agreement problem has been studied and novel solution is derived. The investigated problem is formulated as a nonlinear servomechanism problem, and then an adaptive internal model based controller has been employed to achieve agreement of the agent outputs using local information. Various agent neighborhood topologies have been considered and the overall performance has been verified using fairly simple numerical simulations. Thus a novel solution to the output agreement problem in multi-agent dynamic systems has been found that tolerates presence of uncertainties.

**An Example of Fault Detection and Reconfiguration-Based Tolerance Within Distributed Embedded Control Systems****Matjaž Colnarič, Domen Verber and Matej Šprogar**

This contributed chapter introduces certain novel, recently devised solutions for the fault detection within embedded control systems. These represent a kind of follow-on elaboration on the successful IST FW5 project IFATIS, which has been carried out at the authors' Laboratory for Real-Time Systems of the Faculty of Electrical Engineering and Computer Science in Maribor. The topic is first re-elaborated and the overall results of the original project presented to some extent. Then, in continuation, certain later enhancements and improvements are shown all together with original implementations of specific parts. In particular, the discrete FPGA- and PSoC-based fault monitoring cells are given proper attention. All the novel improvements are discussed via properly emphasized presentation.

### **Predictive Control of Thermal Processes in Complex Industrial Furnaces** **Goran S. Stojanovski, and Mile J. Stankovski**

This chapter presents a thorough investigation of advanced predictive control methods for industrial thermal processes that have been developed and practically implemented in the ASE Institute Laboratory of the Faculty of Electrical-Electronics Engineering and Information Technologies in Skopje. This research is largely carried out on the grounds of identified representation models of two high-power, industrial furnaces that are operated in our country. Such industrial thermal processes typically require high fuel consumption, and therefore the optimization of the fuel costs is always needed. It is widely known that reducing those costs yields dramatically reduced costs of the final product delivered by the industrial plant. For this purpose, the advanced predictive control methods appear especially tailored for furnace thermal processes, since employing predictive control techniques enforces, at the same time, the plant to achieve both faster response and increased robustness. This is clearly supported by both experimental and simulation results are obtained.

### **Closed-Loop Control with Evolving Gaussian Process Models** **Juž Kocijan and Dejan Petelin**

This contribution presents a novel development in the design of control systems that is based on employing evolving Gaussian process (GP) models. The GP models are known to provide a probabilistic, nonparametric modeling approach for black-box identification of nonlinear dynamic systems. They can highlight areas of the input space where prediction quality is poor, by indicating the higher variance around the predicted mean, which may occur due to either the lack of data or the underlying complexity. While the GP models are Bayesian models, the output has normal distribution, expressed in terms of mean and variance. The evolving GP model is the conceptual approach within which various ways of model adaptations can be used. If the prior knowledge about the system to be controlled is scarce or the plant system varies with either the time or the operating region, then this control problem can be solved with an iterative method that adapts the model by means of information obtained with streaming data and thus concurrently optimizes hyper-parameter values.

## **Part V: Novel Control Ideas and Variable-Structure Systems Control**

### **Attenuation of Uncertain Disturbances Through Fast Control Inputs** **Alexander B. Kurzhanski and Alexander N. Daryin**

In this chapter, there is presented a new class of controls that ensure an effect similar to the one produced by conventional matching conditions between control and disturbance inputs in a linear system. However, in this study a broader class of

such inputs has been obtained. This is due to an application of piecewise-constant control functions with varying amplitudes, generated by approximations of “ideal controls” which are linear combinations of delta-functions and their higher order derivatives. Such a class allows for calculation of feedback control solutions by solving problems of open-loop control, thus reducing the overall computation burden. It is believed that this control approach does open a new prospect for future developments of control techniques.

### **Sliding Manifold Design for Linear Systems with Scalar Unmatched Disturbances**

**Boban Veselić, Branislava Draženović and Čedomir Milosavljević**

This chapter presents an efficient sliding manifold design method that minimizes the impact of unmatched disturbances on sliding mode (SM) dynamics in variable-structure control systems. Although variable-structure control systems are known to be insensitive to so-called matched disturbances in ideal sliding mode, nonetheless they are vulnerable to the unmatched ones. The system sensitivity upon an unmatched constant external disturbance is evaluated through the steady state vector norm. An infinite set of the sliding hyper-planes that minimize the chosen optimization criterion is determined. A way of selecting a manifold out of that set that provides adopted SM dynamics is also suggested. The proposed approach has been demonstrated on several numerical examples and investigated by means of computer simulations.

### **Sliding Mode Based Anti-Lock Braking System Control**

**Dragan S. Antić, Darko B. Mitić, Zoran D. Jovanović,  
Staniša Lj. Perić, Marko T. Milojković and Saša S. Nikolić**

This chapter presents the results of a thorough investigation of the anti-lock braking system control by means of sliding mode control. There are considered different continuous- and discrete-time sliding mode control (SMC) techniques in the control of anti-lock braking system (ABS). The SMC is found a right choice for its control because of its robust characteristics in the view that inherently the ABS is characterized by nonlinear and uncertain dynamics. The survey of continuous-time SMC algorithms based on nonlinear models of ABS is given first. Then, the discrete-time nonlinear model of ABS is derived, and the overview of existing discrete-time SMC techniques is presented. The experimental results are given to verify the effectiveness of the investigated SMC methods.

### **Switching Frequency Optimization of DC/AC Inverters Using Sliding Mode** **Khalifa Al-Hoseni and Vadim I. Utkin**

This chapter investigates the application of sliding mode in order to achieve the switching frequency optimization of DC/AC inverters. It is common that a DC/AC converter for three-phase load is designed for controlling two variables such as speed and flux of an AC motor. An additional degree of freedom can be utilized to minimize the switching frequency, which depends on the voltage of the load neutral point. A methodology of switching frequency minimization is proposed in the

framework of the modified hysteresis control. The load neutral point voltage is selected as the third variable to be controlled. First, the tracking system algorithm is developed and then optimization with the switching frequency as a criterion is performed by a proper choice of the reference input for the neutral point voltage. The system accuracy is determined by the width of hysteresis loop and is the same for any switching frequency.

### **Discrete-Time Sliding-Mode Servo Systems Design with Disturbance Compensation Approach**

**Čedomir Milosavljević, Branislava Draženović and Boban Veselić**

In this chapter, there is presented a novel discrete-time sliding mode control design employing a new disturbance compensator. This novel contribution is an essentially chattering-free, discrete-time, sliding mode, control algorithm with a new combined disturbance compensator. It is based on switching function measurement only. The overall system behaves as a high accuracy tracking system with an excellent compensation of matched disturbances. Thus the proposed servo system design represents a new design synthesis solution to this fundamental control engineering problem. Properties of the proposed design method are demonstrated on a velocity and a positional servo system. Analytically derived results as well as the experimental ones have demonstrated a superior performance in comparison with the existing designs.

### **Pragmatic Design Methods Using Adaptive Controller Structures for Mechatronic Applications with Variable Parameters and Working Conditions**

**Stefan Preitl, Radu-Emil Precup, Zsuzsa Preitl, Alexandra-Iulia Stînean, Claudia-Adina Dragoş and Mircea-Bogdan Rădac**

This chapter presents an exploration study of two pragmatic design methods for controllers dedicated to mechatronic applications working under variable conditions. Adaptive structure of the control algorithms are known to be rather important for such applications. Basically, the design is founded on two extensions of the modulus optimum method and of the symmetrical optimum method (SO-m): the extended SO-m and the double parameterization of the SO-m (2p-SO-m). Both methods, which are attributed to the authors, make use of specific PI(D) controllers that are capable of ensuring high control performance in terms of: increased value of the phase margins, improved tracking performance, and efficient disturbance rejection. A short and systematic presentation of the methods and digital implementation aspects using an adaptive structure of the algorithms for industrial applications are given. Application deals with a cascade speed control structure for driving systems with continuously variable reference input, moment of inertia, and disturbance.

Complex Systems

Relationships between Control, Communications and  
Computing

Dimirovski, G.M. (Ed.)

2016, LXXVI, 652 p. 318 illus., 118 illus. in color.,

Hardcover

ISBN: 978-3-319-28858-1