Preface

There are many real systems which can be modelled by dynamical equations. With the increasing requirement for high levels of system performance, it is imperative to deal with more complex systems as dynamical systems used to model reality have become more and more complex. The complexity mainly lies in nonlinearity, uncertainty, time delay, system singularity, strong interconnection, stochastic process, and so forth. The advancement of both scientific technology and control theory has provided the possibility to investigate complex dynamical systems. Study on complex systems becomes increasingly important, which has provided renewed impetus for development of novel techniques and skills for complex control systems.

Complex systems are pervasive in many area of science and we find them every day and everywhere. Examples include financial markets, highway transportation networks, telecommunication networks, world and country economies, social networks, immunological systems, living organisms, computational systems and electrical and mechanical structures. Complex systems are often composed of large number of interconnected and interacting entities exhibiting much richer global scale dynamics than they could be inferred from the properties and behaviour of individual entities. Complex systems are studied in many areas of natural sciences, social sciences, engineering and mathematical sciences.

This book addresses the nonlinear and complex system models considering the dynamical analysis, control, and applications. It involves modeling, non-ideal systems and applications, synchronization, and control for nonlinear systems, such as mechanical, electrical, electromechanical, mechatronic, and very complex systems. This book is intended to be a major reference book for scientists and engineers interested in applying new computational and mathematical tools for solving the complicated problems of mathematical modeling, simulation and control.

This book is mainly focused on the recent achievements and applications in the field of control and analysis for complex systems with a special emphasis on how to solve various control design and/or observer design problems for nonlinear systems, interconnected systems, and singular systems. The considered system is expected to involve at least two of the features such as nonlinearity, disturbances/uncertainty, fault, time delay, interconnections between subsystems, system singularity, stochastic process, and comparison between simulation and experiments.

The main advantage of this book that it is multi-disciplinary and it will attract a lot of researchers working in Control, Automation, system dynamics, simulations, modeling and related fields. With a broad coverage of the contents essential for the analysis and design of various control problems in control engineering practice, this book can also be used as a handy desk top reference during control applications.

This special issue is to improve the dissemination of advanced research in the area of Dynamical Systems and Control Theory that can fulfill the anytime-anywhere access dream. Original research papers are solicited in any aspect of innovative Dynamical Systems and Control Theory.

ORGANIZATION OF THE BOOK

This well-structured book consists of 19 full chapters. They are organized into two sections.

Section 1: Advances in Control and Chaotic Systems
Section 2: Applications of Dynamical Systems

Book Features

- The book presents the dissemination of advanced research in the area of Dynamical Systems and Control Theory
- The book chapters are lucidly illustrated with numerical examples and simulations.
- The book chapters discuss details of engineering applications and future research areas.
- The book chapters give a good literature survey with a long list of references.

The chapters deal with the recent research problems in the areas of system dynamics, automation, control engineering, intelligent control, chaotic systems and applications.

SUMMARY OF THE BOOK CHAPTERS

Section 1 contains Chapters 1-13 focusing on the area "Control and Chaotic Systems."

Chapter 1 describes a method for designing decentralized simulation and control architecture for multiple robot systems based on the discrete event net models. Extended Petri nets are adopted as an effective tool to describe, design and control cooperative behavior of multiple robots based on asynchronous, concurrent processes. By hierarchical decomposition of the net model of the overall system, global and local Petri net models are assigned to the upper level and the lower level controllers, respectively. For the lower level control, individual net models of robots are executed on separate local controllers. The unified net representation for cooperative control is also proposed. Overall control software is implemented and executed on a general hierarchical and distributed control architecture corresponding to the hardware structure of multiple robot systems.

In Chapter 2, a compensation for systems with saturation and backlash in series to the actuator is studied in order to obtain the proposed control strategy. The multivariable Proportional Integral (PI) H_∞ loop shaping design for mechanical systems with backlash is implemented in this chapter due to frequency domain characteristics. This approach is done by implementing the coprime factorization of a linearized model following the loop shaping design procedure. The PI H_∞ control strategy shown in this chapter consists in implementing two weighting functions as a pre-compensator and post compensator considering the linearized model of the nonlinear dynamics of mechanical systems according to their frequency domain properties. One of the main issues overcame in this study, is that the backlash nonlinearity is modeled implementing a describing function, something that it not only allows to ease the design of the proposed control strategy but also to find the limit cycles frequencies and periods. The describing function approach consists in the implementation of Fourier series to obtain a linear model of the backlash and other nonlinearities and to obtain a feasible loop shaping controller design. Also in this chapter, a frequency analysis is explained for this kind of mechanical systems using the Nyquist and the positivity criterion in order to analyze the stability properties of this kind of systems, which can be considered as an important contribution of this study. It is important to remark that the parameter tuning of the PI gains is done by particle swarm optimization (PSO) where an objective function is minimized in order that the system variables reach the equilibrium point faster and accurately. Finally, the stabilization of a cart-pendulum system implementing the proposed control strategy is shown corroborating the effectiveness of this approach.

In Chapter 3, the management of a hybrid renewable energy system is optimized by intelligent approach based on particle swarm optimization comprising a shaded photovoltaic generator and a wind generator. The main objective of this work focuses on the optimization of the management of multi-source generators by intelligent techniques. Following a bibliographic study on the various hybrid technologies, the study has focused on the development of ordering strategies to meet specific requirements during the operation of photovoltaic and wind generators. In this context, attention was focused on the conversion of wind energy with particular interest to the control of the turbine pitch angle. In fact, this control is a practical technique for regulating the power generated above the nominal wind speed. Since the conventional methods usually uses a PI regulator to control the wind turbine pitch angle, the mathematical model of the system should be well known. As meta-heuristic methods can have potential when the system is non-linear, in this work a new PSO-based regulation technique is developed whose detailed and specific knowledge about the system is not required. Subsequently, the phenomenon of partial shading for photovoltaic generators was addressed. This phenomenon is responsible for the appearance of several peaks in the characteristics of the semi-shaded GPV. In order to circumvent the limitations of conventional techniques, an advanced technique based PSO has been proposed and to differentiate between the global maximum and the local maximum. The comparative study between the different methods developed stressed the robustness and performance of MPPT commands based on meta-heuristics. The studied wind /PV system was then integrated into a conversion chain coupled to the electrical network and controlled by power converters. The results obtained allowed to validate the simulation of the energy behavior of the studied system and to check the performance of the PSO control proposed in particular for the smoothing of the generated power.

In Chapter 4, the design of a low order controller for decoupled MIMO systems is proposed. The main objective of this controller is to guarantee some closed loop time response performances such as the settling time and the overshoot. The controller parameters are obtained by resolving a non-convex optimization problem. In order to obtain an optimal solution, the use of a global optimization method is suggested. In this work, the proposed solution is the GGP method. The principle of this method consists on transforming a non-convex optimization problem to a convex one by some mathematical transformations. So as to accomplish the fixed goal it is imperative to decouple the coupled MIMO systems. To approve the controllers' design method, the synthesis of fixed low order controller for decoupled TITO systems is presented firstly. Then, this design method is generalized in the case of MIMO systems. Simulation results and a comparison study between the presented approach and a PI controller are given in order to show the efficiency of the proposed controller. It is remarkable that the obtained solution meets the desired closed loop time specifications for each system output. It is also noted that by considering the proposed approach the user can fix the desired closed loop performances for each output independently.

Chapter 5 investigates the multi-switching combination synchronization of three non-identical chaotic systems via active control technique. In recent years, some advances have been made with the idea of multi-switching combination synchronization. The different states of the master systems are synchronized with the desired state of the slave system in multi-switching combination synchronization scheme. The relevance of such kinds of synchronization studies to information security is evident in the wide range of possible synchronization directions that exist due to multi-switching synchronization. The idea of multi-switching combination synchronization is implemented on three non-identical recently constructed novel chaotic systems. Brief analysis of the novel chaotic systems is also discussed. Numerical simulations justify the validity of the theoretical results discussed.

Chapter 6 discusses the application of evolutionary techniques in Load Frequency Control (LFC) in power systems. It gives introduction to evolutionary techniques. Then it presents the problem formulation for load frequency control with Evolutionary Particle Swarm Optimization (MAACPSO). It gives the application of Particle Swarm Optimization (PSO) in load frequency control, also it illustrates the use of an Adaptive Weight Particle Swarm Optimization (AWPSO), Adaptive Accelerated Coefficients based PSO, (AACPSO) Adaptive Accelerated Coefficients based PSO (AACPSO). Furthermore, and it introduces a new modification for AACPSO technique (MAACPSO). The new technique will be explained inside the chapter, it is abbreviated to Modified Adaptive Accelerated Coefficients based PSO (MAACPSO). A well-done comparison will be given in this chapter for these above-mentioned techniques. A reasonable discussion on the obtained results will be displayed. The obtained results are promising.

In Chapter 7, an Induction Motor (IM) controlled with a Direct Torque Control (DTC) is used to control the photovoltaic panel position. The conventional DTC is chosen thanks to its capability to develop the maximum of torque when the motor is standstill. However, the DTC produces a torque with high ripples and it is suffer from the flux demagnetization phenomenon, especially at low speed. To overcome these problems, two DTC approaches are proposed in this chapter, which are: (i) the DTC based on the fuzzy logic and (ii) the DTC based on Space Vector Modulation (SVM) and proportional Integral (PI) controllers (DTC-SVM-PI). The suggested approaches are implemented on a Field Programmable Gate Array (FPGA) Virtex 5 circuit in order to reduce the sampling period of the system and the delay in the control loop. The simulation and hardware implementation results demonstrate that the DTC-SVM-PI offers best the results in terms of ripples.

Chapter 8 discusses some modern techniques to get the best possible tuning controller parameters for an automatic voltage regulator (AVR) system of a synchronous generator. It was necessary to use PID controller to increase the stability margin and to improve performance of the system. Some modern techniques were defined. These techniques as Particle Swarm Optimization (PSO), also it explains the use of the Adaptive Weight Particle Swarm Optimization (AWPSO), Adaptive Acceleration Coefficients based PSO, (AACPSO), Adaptive Acceleration Coefficients based PSO (AACPSO). Also, it presents a new adjustment for AACPSO technique, Modified Adaptive Acceleration Coefficients based PSO (MAAPSO) is the new technique which will be conversed in this chapter, A discussion of the results of the all methods used will be given in this chapter. Simulation for comparison between the proposed methods will be displayed. The obtained results are promising.

Chapter 9 presents a new method for Loss of Excitation (LOE) faults detection in Hydro-generators using Adaptive Neuro Fuzzy Inference System (ANFIS). The investigations were done under a complete Loss of Excitation conditions, and a partial Loss of Excitation conditions in different generator loading conditions. In this research work, four different techniques are discussed according to the type of inputs to the proposed ANFIS unit, the generator terminal impedance measurements (R and X) and the generator terminal voltage and phase current (V_{trms} and I_a), the positive sequence components of the generator terminal voltage magnitude, phase current magnitude and angle ($|V_{+ve}|$, $|I_{+ve}|$ and $\angle I_{+ve}$) in addition to the stator current 3rd harmonics components (magnitudes and angles). The proposed techniques' results are compared with each other and are compared with the conventional distance relay response in addition to other techniques. The promising obtained results show that the proposed technique is efficient.

In Chapter 10, a new technique has been proposed for reducing the harmonic content of a three-phase PWM rectifier connected to the networks with a unit power factor and also provide decoupled control of the active and reactive instantaneous power. This technique called direct power control (DPC) is based on artificial neural network (ANN) controller, without line voltage sensors. The control technique is based on well-known direct torque control (DTC) ideas for the induction motor, which is applied to eliminate the harmonic of the line current and compensate for the reactive power. The main idea of this control is based on active and reactive power control loops. The DC voltage capacitor is regulated by the ANN controller to keep it constant and also provides a stable active power exchange. To test the feasibility and functionality and robustness of the Artificial Neural Network Controller (ANN), various simulations scenarios have been performed. The simulation results are very satisfactory in the terms of stability and total harmonic distortion (THD) of the line current and the unit power factor.

In Chapter 11, the dynamics of a particular topology of Colpitts oscillator with fractional order dynamics is presented. The first part is devoted to the dynamics of the model using standard nonlinear analysis techniques including time series, bifurcation diagrams, phase space trajectories plots, and Lyapunov exponents. A PSPICE simulation of the nonlinear dynamics of the oscillator are presented in order to confirm the ability of the proposed Colpitts model to accurately describe/predict both the regular and chaotic behaviors of the oscillator with the fractional order dynamics. One of the major results of this innovative work is the numerical finding of a parameter region in which the fractional order Colpitts oscillator's circuit experiences multiple attractors' behavior (i.e., coexistence of two different periodic and chaotic attractors). This phenomenon was not reported previously in the Colpitts circuit (despite the huge amount of related research works) and thus represents an enriching contribution to the understanding of the dynamics of Chua's oscillator. The second part of this chapter deals with the synchronization of fractional order system. Based on fractional-order Lyapunov stability theory, this chapter provides a novel method to achieve generalized and phase synchronization of two and network fractional-order chaotic Colpitts oscillator's respectively. Finally, simulations are given to verify the effectiveness of the proposed control approach.

In Chapter 12, a dynamical model that describes the interaction between the HIV virus and the human immune system is presented. This model is used to investigate the effect of antiretroviral therapy, consisting of RTI and PI drugs, along with the result of undesired treatment interruption. Furthermore, the effect of both drugs can be combined into a single parameter that further simplifies the model into a single input system. The value of the drug inputs can be adjusted so that the system has the desired equilibrium. Drug administration can also be adjusted by a feedback control law which although linearizes the system, may have issues in its implementation. Furthermore, the system is linearized around the equilibrium, leading to a system of linear differential equations of first order that can be integrated into courses of control systems engineering, linear and nonlinear systems in higher education.

Chapter 13 work announces a new four-dimensional hyperchaotic system having two positive Lyapunov exponents, a zero Lyapunov exponent and a negative Lyapunov exponent. Since the sum of the Lyapunov exponents of the new hyperchaotic system is shown to be negative, it is a dissipative system. The phase portraits of the new hyperchaotic system are displayed with both two-dimensional and three-dimensional phase portraits. Next, the qualitative properties of the new hyperchaotic system are dealt with in detail. It is shown that the new hyperchaotic system has three unstable equilibrium points. Explicitly, it is shown that the equilibrium at the origin is a saddle-point, while the other two equilibrium points are saddle-focus equilibrium points. Thus, it is shown that all three equilibrium points of the new hyperchaotic system are unstable. Dynamical properties such as symmetry and invariance are also discussed for the new hyperchaotic system. Furthermore, Lyapunov exponents and Kaplan-Yorke dimension are derived for the new hyperchaotic system. Next, new results are derived for the global stabilization for the new hyperchaotic system with unknown parameters using adaptive control. Also, new results are derived for the complete hyperchaos synchronization of a pair of identical new hyperchaotic systems with unknown parameters, called as *master* and *slave* systems, using adaptive control. All the new control and synchronization results for the new hyperchaotic system are established using Lyapunov stability theory. Numerical simulations with MATLAB have been shown to validate and demonstrate all the new results derived in this paper. Finally, a circuit design of the new hyperchaotic system is implemented in MultiSim to validate the theoretical model.

Section 2 contains Chapters 14-19 focusing on the area “Applications of Dynamical Systems.”

Chapter 14 investigates the effect of vehicle dynamics control systems (VDCS) on both the collision of the vehicle body and the kinematic behaviour of the vehicle’s occupant in case of offset frontal vehicle-to-vehicle collision. The study also investigates the full-frontal vehicle-to-barrier crash scenario. A unique 6-Degree-of-Freedom (6-DOF) vehicle dynamics/crash mathematical model and a simplified lumped mass occupant model are developed. The first model is used to define the vehicle body crash parameters and it integrates a vehicle dynamics model with a vehicle front-end structure model. The second model aims to predict the effect of VDCS on the kinematics of the occupant. It is shown from the numerical simulations that the vehicle dynamics/crash response and occupant behaviour can be captured and analysed quickly and accurately. Furthermore, it is shown that the VDCS can affect the crash characteristics positively and the occupant behaviour is improved in the full and offset crash scenarios.

Chapter 15 presents a study on the transportation mode choice behaviour of individuals with different socio-economic status. A previously developed system dynamics model has been adopted by differentiating the population mass into upper, middle and lower classes. The simulation experiments with the model revealed that generally the upper-class individuals would be more inclined in using private car (PC) instead of public transportation (PT) when their tendency is compared to middle and lower-class individuals. It was also observed that lower class individuals would be more willing to use PT instead of PC when their tendency is compared to middle and upper-class individuals. As such, it would be difficult to encourage the upper-class individuals to use PT instead of PC, and it would be successively easier to do so in the case of middle and lower-class individuals. However, the results also indicated that under certain different circumstances, the upper-class individuals would also prefer to go for PT, and the lower-class ones could prefer to own and use PC instead of PT.

Chapter 16 describes a system dynamics model developed for forecasting, prioritization, and distribution of critical supplies during relief operations in case of a hurricane event, while integrating GIS information. Development of alternates’ routes selection through vehicle routing procedures and the results incorporation into this system dynamics model allows to make decisions about the operation in case of a major catastrophe and any preparation for future events. The model developed is also able to (1) establish people’s decision and transportation characteristics that determine evacuation time; (2) simulate the behavior of key variables due to the relation between hazard level and people’s decision to evacuate; (3) estimate for each natural hazard level the time frequency to order and the order size of each relief supply to be needed in shelters and points of distribution; and (4) reveal which routes cause more delays during relief supplies distribution.

Chapter 17 investigates the investment in IT by an Indian based logistics company on the logistics performance. Technologies like RFID, EDI, GPS/GIS and ERP are chosen for improving processes like tracking and tracing, planning and forecasting, transportation automation, coordination with suppliers and customers and decision optimization. Simulations are carried out using system dynamics modelling. The model is validated and sensitivity analysis is performed. Scenarios are generated under optimistic and pessimistic conditions.

Chapter 18 examines the nature of vulnerability of smallholders' food security caused by above conditions in the context of system dynamics modelling. The results show that smallholders co-exist whereby the non-resilient households offer labor to the resilient households for survival during turbulent seasons irrespective of the magnitude of external shocks and stressors. In addition, non-resilient households cannot be liberated by external handouts but rather through building their capacity for self-reliance. Using simulation evidence, this study supports the claim that in the next decade, only resilient households will endure the extreme situations highlighted above. Future research that employ similar systems-based methods are encouraged to explore how long-term food security among smallholders can be sustained.

In Chapter 19, the design and development of a computational model of the cardiovascular system is presented for patients who have undergone the Fontan operation. The model has been built from a physiological basis, considering some of the mechanisms associated to the cardiovascular system of patients with univentricular heart disease. Thus, the model allows the prediction of some hemodynamic variables considering different physiopathological conditions. The original conditions of the model are changed in the Fontan procedure and these new dynamics force the hemodynamic behaviours of the different considered variables. The model has been proved considering the classic Fontan procedure and the techniques from the lateral tunnel and the extracardiac conduit. The results compiled knowledge of several cardiovascular surgeons with many years of experience in such interventions, and have been validated by using other authors' data. In this sense, the participation of a multidisciplinary team has been considered as a key factor for the development of this work.

AUDIENCE

The book is primarily meant for researchers from academia and industry, who are working in the research areas – Computer Science, Information Technology, Engineering, Automation, Chaos and Control Engineering. The book can also be used at the graduate or advanced undergraduate level as a text-book or major reference for courses such as mathematical modeling, computational science, numerical simulation, nonlinear dynamical systems and chaos, control systems, applied artificial intelligence, and many others.

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