Editorial

Preservation of Relevant Properties of Interconnected Dynamical Systems over Complex Networks

The inference and analysis of properties of solutions of differential equations is at the core of qualitative theory of dynamical systems. Understanding the conditions under which these properties are conserved under interconnections and coordinate transformations is a fundamental paradigm in the qualitative systems theory. Particularly, the concepts of passivity and dissipativity, which are embedded in the systems theory decades ago, are increasingly relevant in nowadays technological developments in the energy sector. Another property of special interest is the capacity of dynamical systems to synchronize or to desynchronize through weak interaction. Indeed, the study of synchronization is ubiquitous in basic sciences, such as physics, biology, medicine, as well as in disciplines linked to engineering and applied mathematics, such as computer science and control theory.
On one hand, the study of dissipativity and energy exchange, as well as understanding the capacity of dynamical systems to (de)synchronize due to their interaction over networks (possibly with changing topology), has a major impact in a number of scientific and technological areas. On the other hand, qualitative systems theory contributes with original and efficient analytical methods. Thus, driven by authentic technological and scientific paradigms.

The objective of this special issue is to gather some the latest developments on preservation of relevant properties of interconnected dynamical systems from the systems theory perspective. The published papers provide new ideas and approaches, clearly indicating the advances made in problem statements, methodologies, or applications with respect to the existing results.

This Special Issue provides our readers with a focused set of peer-reviewed articles to reflect recent advances in the state-of-the-art design techniques as well as other important aspects of the field. The Special Issue also serves as a forum for researchers to exchange their later results, as well as to stimulate further research and development in this fast-growing area. The Special Issue contains 9 papers that address various important issues about synchronization, passivity, and properties in relationship with robustness, fragility, and under perturbations and transformations for dynamic systems and networks.

To demonstrate relevant ideas and concepts motivating this Special Issue development let us briefly present all papers included here.

The paper "Generalized multistable structure via chaotic synchronization and preservation of scrolls" by Eduardo Jiménez.; Luis Javier Ontanon, Javier S Gonzalez-Salas, Eric Campos-Cantón, and Alexander N Pisarchik, studies interconnected multi-scroll chaotic systems in master-slave configuration. It focuses to an interesting phenomenon when the master presents different number of scrolls than the slave and how to reach preservation of the number of scrolls in the slave. In particular, paper introduces and demonstrates the so-called multi-modal generalized synchronization meaning that a functional relation between the master and the slave subsystems exists.

The paper "Preservation of a two-wing Lorenz-like attractor with stable equilibria" by L.J. Ontanon-Garcia and E. Campos-Canton constructs a feedback control that stabilizes two equilibria of the Lorenz system while preserving its two-wing attractor. The resulting forced system generates at the same time bi-stability, i.e. its trajectory settles down at one stable equilibrium point determined by the initial condition for the zero forcing signal. Thanks to the variation of the coupling strength of the control signal the symmetric equilibria of the Lorenz system move as well as their basins of attraction. The preservation of a two-wing Lorenz-like attractor is therefore possible using the switching control driven by these dynamic basins of attraction.

The paper "Stabilization and passiffication of distributed-order fractional linear systems using methods of preservation" by Guillermo Fernandez-Anaya, Jose-Job Flores- Godoy, Armando-Fabian Lugo-Peñaloza, and Rodrigo Muñoz, deals with the stabilization and passiffication of a class of distributed-order linear time-invariant systems. It further develops and extends the classical methodology based on the preservation of stability and passivity of classical linear time-invariant system in the frequency domain. More precisely, these classical results are extended to a more general family of matrix functions. Passiffication and stabilization of the distributed order linear system is then successfully addressed using the above mentioned novel methodology.

The paper "Electronic circuit implementation of the chaotic Rulkov neuron model" by Alexandre Wagemakers and Miguel A. F. Sanjuan addresses the electronic implementation of a map-based neuron model, more precisely, the chaotic Rulkov neuron model, that can be easily transferred on a large scale integration circuit. This opens possibility to use it as a framework for the simulation of large networks of neurons. The Rulkov model is a map-based neuron model that has a surprising abundance of features, such as periodic and chaotic spiking and bursting. The above mentioned circuit implementation requires 18 MOS transistors only and therefore offers new and efficient perspectives for building large networks of neurons within a single device.

The next paper "Discrete-Time Synchronization Strategy for Input Time Delay Mobile Robots" by Rafael Castro-Linares, Martín Velasco-Villa, Francisco Rosales-Hernández, Basilio del Muro-Cuéllar, Miguel Angel Hernández-Pérez, offers a new synchronization strategy for a group of differentially driven mobile robots subject to input time-delayed control signals. This synchronization strategy is developed to be a basis for the novel control strategy using two main components: a specific formation for the group of robots and the tracking of a particular desired trajectory. Furthermore, the proposed control strategy enables the consideration of the causal feedback laws avoiding the use of an additional prediction strategy that counteracts the undesired input time-delay effects. Real-time experiments for the group of three mobile robots and an indoor absolute localization system based on artificial vision demonstrate the efficiency of this synchronization strategy.

The paper “Robust Synchronization of a Class of Chaotic Networks” by Sergej Celikovsky, Volodymyr Lynnyk, and Guanrong Chen, presents an analysis of synchronization of a chaotic network having the generalized Lorenz system at each node with a bi-directional synchronizing scalar signal through each edge. In particular, the robustness of the resulting synchronization is studied when some connections are added or removed. It is shown that for the so-called minimal synchronizable configuration one can always achieve global exponential synchronization. On the contrary, redundant connections lead to the result that only semi-global synchronization is possible. Here, both synchronizability and minimality are defined with respect to the properties of the network topology.

In the paper "On stabilisability of 2-D MIMO shift-invariant systems" the authors Petr Augusta and Petra Augustova concentrate on the linear spatially-distributed time-invariant two-dimensional systems with multiple inputs and multiple outputs and with control action based on an array of sensors and actuators connected to the system. The system is described by the bivariate matrix polynomial fraction. Stabilization of such systems is based on the relationship between stability of a bivariate polynomial and positiveness of a related polynomial matrix on the unit circle. Such matrices are not linear in the controller parameters, however, in simple cases, a linearizing factorization exists. It allows to describe the control design in the form of a linear matrix inequality. In more complicated cases, linear sufficient conditions are given.

The paper "Application of symbolic dynamics to characterize coordinated activity in the context of biological neural networks" begins recalling that the generation of coordinated patterns of activity in the nervous system is essential to drive complex behavior in animals, both vertebrates and invertebrates. In many cases rhythmic patterns of activity are the result of the cooperation between groups of small number of neurons bearing overall network dynamics. These patterns encode information in different spatio-temporal scales based on the history-dependent capabilities of neuronal dynamics. In this work David Arroyo, Roberto Latorre, Pablo Varona, F. B. Rodríguez analyze a simple neural network, the Central Pattern Generator, by identifying and characterizing the dynamical patterns sustaining the coordination among the constituent neurons. The description of the corresponding coordination states is performed with the guidance of the theory of applied symbolic dynamics. They show that symbolic dynamics enables the automatic detection of meaningful events with low computational cost, endorsing the analysis of both individual and global neuronal dynamics. Furthermore, symbolic dynamics can be used to compute entropy and distinguish between networks with the same topology but different dynamics for the underlying nodes.

Finally, the paper "Application of functional derivatives to analysis of complex systems" by Zdenek Beran and Sergej Celikovsky presents the functional derivatives apparatus and uses it to study the mathematical modeling of complex systems. First, the relation between functional derivatives and total differentials in Banach spaces is addressed. It turns out that the functional derivatives are a special case of total differentials when the underlying function spaces are appropriately chosen. Local and global existence theorems for the linear equations in total differentials are proved. Consequently, a total integrability conditions are derived for the case of equations with the functional derivatives. Further, it is shown that the initial problem for the nonlinear Lorenz system model described by a system of ordinary differential equations can be transformed into an initial problem for the linear equation with the functional derivatives. Some other illustrative examples are included as well.

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