International Journal of Bifurcation and Chaos, Vol. 22, No. 2 (2012) 1202001 (4 pages)
© World Scientific Publishing Company
DOI: 10.1142/S0218127412020014

INTRODUCTION

M. A. AZIZ-ALAOUI
LMAH, University of Le Havre, 25 rue Ph. Lebon,
BP 540, 76058 Le Havre Cedex, France
aziz.alaoui@univ-lehavre.fr

CYRILLE BERTELLE
LITIS, University of Le Havre, 25 rue Ph. Lebon,
BP 540, 76058 Le Havre Cedex, France
cyrille.bertelle@univ-lehavre.fr

XINZHI LIU
Department of Applied Mathematics, University of Waterloo,
Waterloo, Ontario N2L 3G1, Canada
xzliu@uwaterloo.ca

Received December 15, 2011

One of the main characteristics of complexity is the emergence of properties due to dynamical processes. This special issue has put together a unique collection of articles written by leading researchers and experts around the globe on recent advances in complex systems and applications, in various fields of science and engineering. It focuses not only on equation-based modeling of eco- or bio-systems analysis but also on the study of eco- or bio-complexity and global emergent properties and self-organization, resulting from various interactions.

Keywords: Complex systems; complex networks; self-organization; emergence; dynamical systems; chaos; synchronization.

While twenty years ago complex dynamics in a wide variety of systems was somewhat a novelty to many of us, it has literally become an indispensable part of our toolkits today. Besides, applications of complex dynamics such as chaos and bifurcations have appeared in many areas of engineering, physics, natural and social sciences. The novelty of the new science of complexity is not so much a challenge to formalize phenomena that each of these sciences of disciplines had found and revealed with its own techniques and with its specific language, but it addresses the original trans-disciplinary positioning that connects directly phenomena of different natures. We have to highlight for example, that transition scales characterizing complex systems are mainly independent of the nature of observed objects and systems. The science of complexity is no more a specific tool for a specific field, but it transcends disciplines and is enriched by multidisciplinarity. All these have led to a remarkable change in the way mathematicians, computer scientists, engineers and other scientists interact with dynamics in nonlinear systems.

It is then necessary to establish dialogues between the model and the modeled object, between the modeler and the specialist of the phenomenon. It is a classic and indispensable step in any modeling activity. When it comes to understanding the complexity of phenomena, it is the transfer of scales between micro and macro, between particles and laws, between individuals and societies that needs to be described with meaning. Computer modeling can now go to scale complex simulations where thousands or millions of particles, neurons or individuals interact. As we understood, it is ultimately not the nature of objects that are sources of essential dynamics but their interaction. These interaction systems, networks or dynamic graphs are abstract while the thematician (the informed observer of the specific system) manages to express his knowledge through the network or system interaction. The richness of multidisciplinary approaches through the science of complexity is the major aspect of our special issue contribution.

Although the range of subjects is deliberately wide, there are several core themes which are repeatedly addressed from different angles.

The pre-history of chaos in a rationalist context is taken as a point of departure in [Rössler, 2012], starting out with ancient China. The related ancient-Greek "unmixing theory" is then led over to two simple formally 2-body Hamiltonian systems exhibiting chaotic behavior. When the two masses involved are unequal, "pseudoattractors" are formed. Deterministic statistical "thermodynamics" with its dissipative behavior arises when the potential is repulsive. Deterministic statistical "cryodynamics" arises when the potential is attractive.

Baptista *et al.* [2012] clarifies the relationship between network circuit (topology) and behavior (information transmission and synchronization) in active networks, e.g. neural networks. As an application, they show how to determine a network topology that is optimal for information transmission.

The appearance of infinitely-many period-doubling cascades is one of the most prominent features observed in the study of maps depending on a parameter. They are associated with chaotic behavior, since bifurcation diagrams of a map with a parameter often reveal a complicated intermingling of period-doubling cascades and chaos, see [Sander & Yorke, 2012]. In this very interesting contribution, one can see that period doubling can be studied at three levels of complexity. The first is an individual period-doubling bifurcation. The second is an infinite collection of period doublings that are connected together by periodic orbits in a pattern called a cascade. The third involves infinitely many cascades and a certain parameter value of the map at which there is chaos.

In [Lozi, 2012], the author uses the emergent property of the ultra weak multidimensional coupling of p 1-dimensional Micro dynamical chaotic systems which leads from chaos to randomness, which, together with chaotic sampling and mixing processes, leads to families of Chaotic Pseudo Random Number Generators (CPRNG).

Martinez *et al.* [2012] present techniques of analyzing complex dynamics of cellular automata (CA) with chaotic behavior. CA are well known computational substrates for studying emergent collective behavior, complexity, randomness and interaction between order and chaotic systems.

Complex software networks, as a typical kind of man-made complex networks, have attracted more and more attention from various fields of science and engineering over the past ten years. With the dramatic increase of scale and complexity of software systems, it is essential to develop a systematic approach to further investigate the complex software systems by using the theories and methods of complex networks and complex adaptive systems. Authors in [Wang *et al.*, 2012] attempt to briefly review some recent advances in complex software networks and also develop some novel tools to further analyze complex software networks, including modeling, analysis, evolution, measurement, and some potential real-world applications. It also outlooks some future research topics from engineering viewpoints.

One of the most relevant domains that complex system modeling has to face are biological systems. Several contributions to this Special Issue are related to such systems. Structural aspects of the complexity dynamics are highlighted in [Corson *et al.*, 2012] that lead to the implementation of the morphogenesis of emergent structures in one hand, and also control the synchronization of complex networks on the other hand. Specific applications are proposed to illustrate these two aspects, in urban dynamics and in neural networks.

Models of bursting typically include two subsystems with different timescales leading to fast-slow systems which are studied usually by "geometrical dissection". The fast dynamics exhibit attractors which may bifurcate under the influence of the slow dynamics which is seen as a parameter of the fast dynamics. A generic solution comes close to a connected component of the stable invariant sets of the fast dynamics. As the slow dynamics evolves, this attractor may lose its stability and the solution eventually reaches quickly another connected component of attractors of the fast dynamics and the process may be repeated. Authors in [Vidal & Françoise, 2012] present several new surprising effects like the "amplification of canards" or the "exceptionally fast recovery" on both $(1+1)$-systems and $(2+1)$-systems associated with tritrophic food chain dynamics. Authors also mention their possible relevance to the notion of resilience which has been coined out in ecology.

The paper [Marwan *et al.*, 2012] applies recently introduced measures of complexity for the structural quantification of distal tibial bone, to investigate the temporal structural alteration of trabecular bone.

Classical models of morphogenesis by Murray and Meinhardt and of epidemics by Ross and McKendrick can be revisited in order to consider the colocalizations favoring interaction between morphogens and cells or between pathogens and hosts. The classical epidemic models suppose for example that the populations in interaction have a constant size and are spatially fixed during the epidemic waves, but the presently observed pandemics show that the long duration of their spread, during months or years, imposes to take into account the pathogens, hosts and vectors migration in epidemics, as well as the morphogens and cells diffusion in morphogenesis. That naturally leads authors in [Demongeot *et al.*, 2012] to study the occurrence of complex spatio-temporal behaviors in dynamics of population sizes and also to consider preferential zones of interaction, i.e. the zero-diffusion sets, for respectively building anatomic frontiers and confining contagion domains.

Effects of Refuges and Density Dependent Dispersal on Interspecific Competition Dynamics are studied in [Doanh *et al.*, 2012]. They present a classical interspecific competition model in which individuals compete for a resource on a common patch and can go to a refuge. They study the effects of density dependent dispersal from the competition patch to the refuge on the global outcome of competition.

A Shannon entropy is proposed as a new sleep fragmentation quantification methodology in [Naeck *et al.*, 2012] where authors study the dynamics underlying patient-ventilator interactions during nocturnal noninvasive ventilation. Indeed, noninvasive ventilation is a common procedure for managing patients having chronic respiratory failure. The success of this ventilatory assistance is often linked with patient's tolerance that is known to be related to the quality of the synchronization between patient's spontaneous breathing cycles and ventilatory cycles delivered by the ventilator.

In [Zhang *et al.*, 2012], authors consider a sensor fault reconstruction scheme for nonlinear systems, using the sliding mode observer and adaptive observer. The novelty of this contribution is that it considers the disturbances represented in both the state equation and the output equation.

Authors in [Wagemakers *et al.*, 2012] present an analog circuit implementation of the novel partial control method, that is able to sustain chaotic transient dynamics. The electronic circuit simulates the dynamics of the one-dimensional slope-three tent map, for which the trajectories diverge to infinity for nearly all the initial conditions after behaving chaotically for a while. This is due to the existence of a nonattractive chaotic set: a chaotic saddle. The partial control allows one to keep the trajectories close to the chaotic saddle, even if the control applied is smaller than the effect of the applied noise, introduced into the system.

In [Liu *et al.*, 2012], authors create a multi-scroll chaotic attractor from Chen system by a nonlinear feedback control. The dynamic behavior of the new chaotic attractor is analyzed. Specially, the Lyapunov spectrum and Lyapunov dimension are calculated and the bifurcation diagram is shown.

We hope that this special issue will provide an important impetus to further promote and develop the cutting-edge research on complexity, chaos, bifurcation and stability in mathematical and computational modeling of ecological, biological and environmental systems and more generally interaction-based systems.

The guest editors would like to thank all of the authors who contributed to this Special Section.

References

Baptista, M. S., de Carvalho, J. X., Hussein, M. S. & Grebogi, C. [2012] "Active networks that maximize the amount of information transmission," *Int. J. Bifurcation and Chaos* **22**, 1230008-1–1230008-25.

Corson, N., Aziz-Alaoui, M., Ghnemat, R., Balev, S. & Bertelle, C. [2012] "Modelling the dynamics of complex interaction systems: From morphogenesis to control," *Int. J. Bifurcation and Chaos* **22**, 1250025-1–1250025-20.

Demongeot, J., Gaudart, J., Lontos, A., Mintsa, J., Promayon, E. & Rachdi, M. [2012] "Zero-diffusion domains in reaction-diffusion morphogenetic & epidemiologic processes," *Int. J. Bifurcation and Chaos* **22**, 1250028-1–1250028-23.

Doanh, N. N., Tri, N.-H. & Auger, P. [2012] "Effects of refuges and density dependent dispersal on interspecific competition dynamics," *Int. J. Bifurcation and Chaos* **22**, 1250029-1–1250029-11.

Liu, X. Shen X. (Sherman) & Zhang, H [2012] "Multiscroll chaotic and hyperchaotic attractors generated from Chen system," *Int. J. Bifurcation and Chaos* **22**, 1250033-1–1250033-15.

Lozi, R. [2012] "Emergence of randomness from chaos," *Int. J. Bifurcation and Chaos* **22**, 1250021-1–1250021-15.

Martinez, G. J., Adamatzky, A. & Alonso-Sanz, R. [2012] "Complex dynamics of elementary cellular automata emerging from chaotic rules," *Int. J. Bifurcation and Chaos* **22**, 1250023-1–1250023-13.

Marwan, N., Beller, G., Felsenberg, D., Saparin, P. & Kurths, J. [2012] "Quantifying changes in the spatial structure of trabecular bone," *Int. J. Bifurcation and Chaos* **22**, 1250027-1–1250027-12.

Naeck, R., Bounoiare, D., Freitas, U. S., Rabarimanantsoa, H., Portmann, A., Portier, F., Cuvelier, A., Muir, J.-F. & Letellier, C. [2012] "Dynamics underlying patient-ventilator interactions during nocturnal noninvasive ventilation," *Int. J. Bifurcation and Chaos* **22**, 1250030-1–1250030-17.

Rössler, O. [2012] "Hun Tun versus big bang: How classical chaos implies both 'thermodynamics' and 'cryodynamics'," *Int. J. Bifurcation and Chaos* **22**, 1230007-1–1230007-9.

Sander, E. & Yorke J. A. [2012] "Connecting period-doubling cascades to chaos," *Int. J. Bifurcation and Chaos* **22**, 1250022-1–1250022-16.

Vidal, A. & Françoise, J.-P. [2012] "Canard cycles in global dynamics," *Int. J. Bifurcation and Chaos* **22**, 1250026-1–1250026-13.

Wagemakers, A., Zambrano, S. & Sanjuan, M. A. F. [2012] "Partial control of transient chaos in electronic circuits," *Int. J. Bifurcation and Chaos* **22**, 1250032-1–1250032-10.

Wang, H., He, K., Li, B. & Lu, J. [2012] "On some recent advances in complex software networks: Modeling, analysis, evolution and applications," *Int. J. Bifurcation and Chaos* **22**, 1250024-1–1250024-15.

Zhang, C., Liu, X. & He, J. [2012] "Robust sensor fault reconstruction for nonlinear systems using observers," *Int. J. Bifurcation and Chaos* **22**, 1250031-1–1250031-7.