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EDITORIAL

The study of networks has become one of the paradigms of the science of complexity as well as a fascinating branch of research in applied mathematics, science (metabolic and protein networks, neural networks, genetic regulatory networks, protein folding), sociology (social networks, acquaintances or collaborations between individuals) and engineering (phone call networks, computers in telecommunication networks) [Albert & Barabási, 2002; Bar-Yam, 1997; Boccaletti *et al.*, 2006; Newman, 2003; Newman *et al.*, 2006; Strogatz, 2001; Cohen *et al.*, 2000, 2001].

The wide range of systems in the real world that can be modeled by complex networks show behavioral and structural features in common, and they can be studied by using nonlinear mathematical models and computer modeling approaches. The interest in complex networks has certainly been promoted by the optimized rating of computing facilities, and by the availability of data on large real networks (World Wide Web, cortical networks, citation networks from Scientific Citation Index). This issue focuses on the latest applications of complex networks rather than the theoretical aspects, but also covering topological properties, algorithms and computation tools, models of interactions between complex systems, synchronization and control and some other related topics.

Since the publication of the two seminal papers, by Watts and Strogatz on *small world networks* [Watts & Strogatz, 1998], and by Barabási and Albert on *scale-free networks* [Barabási & Albert, 1999], there is growing interest for complex networks by the large number of papers that have been published about this topic, and the new problems and research lines that have been tackled.

This special issue is about the structure and dynamics of complex networks and it aims to provide a selection of contributed papers that covers a wide range of relevant and modern aspects in the analysis of complex networks, giving a state of the art picture of the field of complex networks. The contributions were selected among those presented at the International Conference Net-Works 2008, held in the University of Navarra, Pamplona (Spain) on June 9–11th, 2008, in cooperation with the Society for Industrial and Applied Mathematics (SIAM) and the American Institute for Mathematical Sciences (AIMS).

The works contained in this special issue are divided into *tutorials*, *papers* and *letters*, covering a wide range of topics not only related to the topological properties of complex network but also to their dynamics and the relationship between them. The issue opens with three tutorials. The first one, by *Almendral, Leyva, Sendiña-Nadal and Boccaletti*, reviews some of the main results in setting **collective (synchronized) behaviors in globally and locally identical coupled oscillators** and the main formalism for the necessary condition to stabilize a synchronous motion is discussed in detail. In addition to this, the case of a growing network of nonidentical oscillators is also briefly described, where the growth process is entirely guided by dynamical rules and the final synchronized state accompanies the emergence of a specific statistical feature (the scale-free property) in the network's degree distribution. The second tutorial, by *Buscarino, Di Stefano, Fortuna, Frasca and Latora*, focuses on **the effect of motion on the spreading of diseases in dynamical social networks of mobile agents**, which has recently attracted considerable attention in the scientific community. The existing relations between dynamical networks of random walkers with jumps and static small-world networks are discussed, including those between

systems of Lévy walkers and scale-free networks. The last tutorial, by *Rosso, De Micco, Larrondo Martin and Plastino*, deals with a generalized **statistical complexity measure** which is a functional that characterizes the probability distribution P associated to the time series generated by a given dynamical system. Several fundamental issues are reviewed such as the selection of the information measure, the choice of the probability metric space and associated distance D, the definition of the so-called *generalized disequilibrium* Q or the adequate way of picking up the probability distribution P associated to a dynamical system or time series under study. It is also indicated that sensible improvements in the final results can be expected if the underlying probability distribution is *extracted* via appropriate consideration regarding causal effects in the system dynamics.

The special issue follows with eleven papers, dealing with different aspects of the topological and dynamical properties of complex networks. The first, by *Cárdenas, Mouronte, Santiago, Feliu and Benito*, analyzes the **topological properties of optical transport networks** and show that the *Synchronous Digital Hierarchy* (SDH) network operated by Telefónica in Spain presents a power-law scaling in the degree distribution and it displays small world properties with a high clustering and short path length similar to the Internet routers network. An *ad-hoc* computational model of such networks is proposed, that considers the network design policies, user demand, geographical location and types of equipment present in the SDH network operated by Telefónica. The second paper, by *da Fontoura Costa, Aparecido Rodrigues and Ribeiro Villas Boas*, deals with the **evolution of complex networks** thorough path-star transformations and optimal multivariate methods. It is also shown, by using canonical projections and maximum likelihood classification, that while the US highways network adheres closely to a geographical network model, its path-star transformation yields a network whose topological properties closely resemble those of the respective airport transportation network. A paper by *Hernández-García, Tuğrul, Herrada, Eguíluz and Klemm* is included that presents, from a numerical point of view, two **branching models for scaling in phylogenetic trees** and the power-law scaling is displayed in both models (in one case by analytical methods, while in the other by numerical methods).

The fourth paper, by *Hövel, Dahlem and Schöll*, studies the **synchronization of coupled neurons** which are modeled as **FitzHugh–Nagumo systems**. The cooperative dynamics between coupled neurons are modified by a local external stimulus in the form of an extended **time-delayed feedback** loop that involves multiple delays weighted by a memory parameter, and investigate if local control applied to a subsystem can allow one to steer the global cooperative dynamics and several measures are considered to quantify the influence on synchronization, including the ratio of interspike intervals, the power spectrum, the interspike interval distribution, and the phase synchronization intervals. It is shown that the control method is more robust for increasing the memory parameter. The next paper, by *Leyva, Sendiña-Nadal, Almendral, Buldú, Li, Havlin and Boccaletti*, considers the response of a random and modular network to the simultaneous presence of two frequencies and it shows that the **competition for controlling the dynamics** of the network results in different behaviors, such as frequency changes or permanent synchronization frustration, which can be directly related to the network structure. As a consequence of these facts a new method for detecting overlapping communities in structured networks is presented. A paper by *Miranda and Burguete* is included, studying the **spatiotemporal phase synchronization** in an array of oscillators, extracting the time-varying topology from the dynamics, which help to understand the phenomenon of interacting oscillators in a 1D convective system and it contributes to clarify also other complex systems exhibiting similar phase chaotic dynamics.

The seventh paper, by *Poncela, Gómez-Gardeñes, Moreno and Floría*, deals with the **cooperative behavior** of agents playing the **Prisoner's Dilemma game in scale-free networks**. It is shown that the survival of cooperation is enhanced with respect to random

homogeneous networks while it decreases when compared to that found in Barabási–Albert scale-free networks. In addition to this, a mean field approximation is presented, which is similar to that used in disease spreading models in complex networks, for studying evolutionary dynamics in networks with no degree-degree correlations and with arbitrary degree distribution. The next paper, by *Schmidt, Zamora-López and Kurths*, analyzes how to reproduce the dynamical behavior of the multilevel model of the **resting-state dynamics of the cortico-cortical connectivity of the mammalian brain** by a strongly simplified model that replaces each cortical area by a single Rulkov map or a neuron model by Izhikevich. It is stated that while the network of interconnected Rulkov maps recreates the patterns of dynamical correlations of the multilevel model, the simulations performed using the Izhikevich model shows that the dynamics does not depend on the underlying topology. A paper by *Torres, de Franciscis, Johnson and Marro* is presented, that reports how the dynamics depend on connectivity in a **model of excitable media** (Amari–Hopfield network with a Hebbian learning rule) and it is shown that there is a strong correlation between wiring topology and network functionality. In addition to this, the nature of the irregular wandering of the activity is described among the stored patterns and also the system critical behavior at the onset of this irregular behavior in the resulting nonequilibrium steady states.

The tenth paper, by *Criado, Romance and Vela-Pérez*, introduces the concept of **hyperstructure** as a new tool for modeling real problems, such as communication networks. This new approach extends the concept of network and hyper-networks and some analytical estimates are presented relating an hyper-structure with the underlying network and hyper-network. The last paper, by *Vidal and Mancini*, analyzes the **synchronization** between identical pairs of **hyperchaotic mathematical systems symmetrically coupled** and the effects of coupling two identical hyperchaotic oscillators of three different origins is studied.

Finally, the special issue also contains six letters. The first one, by *Arévalo, Zuriguel, Ardanza-Trevijano and Maza*, studies the statistics of **third-order loops in force networks of granular materials** and their relationship with force distributions, by showing that almost all the third order loops allocate a force that is below the average and as a consequence, the experimental methods need to determine univocally the topology of the small forces between particles in order to understand completely the jamming transition. A letter by *De Vico Fallani, Astolfi, Cincotti, Mattia, Maksuti, Patidar, Salinari, Marciani, Zouridakis and Babiloni* is included that analyzes the influence of human learning on **functional brain organization** from a network-theoretical perspective, using efficiency measures to characterize the topological changes induced by the learning of a complex visuomotor task with strategic components. The third letter, by *Goñi, Martincorena, Corominas-Murtra, Arrondo, Ardanza-Trevijano and Villoslada*, deals with the use of **random walks** to explore the nodes of a networked system inspired in the information retrieval in **semantic networks**. In particular, the typical next-nearest neighbor movement of walkers is coupled with the possibility that the walkers make a hop to a distant neighbor with some probability and several network topologies (random, Small-World, modular and scale-free) are analyzed by using the mean first passage time of the walks to characterize the efficiency of information search in the different topologies.

The fourth letter, by *Santiago and Benito*, presents some results concerning the connectivity metrics in a natural extension of the class of **heterogeneous preferential attachment models** that shows that the introduction of heterogeneity induces a richer scaling behavior in the degree densities of the models with regards to their homogeneous counterparts. It is also shown that the power-law scaling in the degree distribution of the models is robust in the presence of the offset in the attachment kernel, so that higher offset terms only yield a right shift in the higher bound of the spectrum of scaling exponents in the extended class. The letter by *Tuğrul and Kabakçioğlu* investigates the dynamical properties of the **transcriptional regulation of gene expression** in the yeast *Saccharomyces Cerevisiae*

within the framework of a synchronously and deterministically updated Boolean network model and reports the robustness of gene expression against a binary parameter related with the genes regulatory rules. The last letter, by *Zanin, Buldú and Boccaletti*, deals with the **propagation of perturbations** through spatially distributed **networks of springs** and it is shown that the topological properties of the network are related with the dissipation of the energy within the system. The obtained results are connected with the transmission of information through a complex structure and they could be of potential application to the design of more efficient damping systems.

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References

Albert, R. & Barabási, A. L. [2002] "Statistical mechanics of complex networks," *Rev. Mod. Phys.* **74**, 47–97.

Barabási, A. L. & Albert, R. [1999] "Emergence of scaling in random networks," *Science* **286**, 509–512.

Bar-Yam, Y. [1997] *Dynamics of Complex Systems* (Addison-Wesley, 1997).

Boccaletti, S., Latora, V., Moreno, Y., Chavez, M. & Hwang, D.-U. [2006] "Complex networks: Structure and dynamics," *Phys. Rep.* **424**, 175–303.

Cohen, R., Erez, K., Ben-Avraham, D. & Havril, S. [2000] "Resilience of the Internet to random breakdowns," *Phys. Rev. Lett.* **85**, 4626–4628.

Cohen, R., Erez, K., Ben-Avraham, D. & Havril, S. [2001] "Breakdown of the Internet under intentional attacks," *Phys. Rev. Lett.* **86**, 3682–3685.

Newman, M. E. J. [2003] "The structure and function of complex networks," *SIAM Rev.* **45**, 167–256.

Newman, M. E. J., Barabási, A. L. & Watts, D. J. [2006] *The Structure and Dynamics of Networks* (Princeton University Press, Princeton, NJ), pp. 167–256.

Strogatz, S. H. [2001] "Exploring complex networks," *Nature* **410**, 268–276.

Watts, D. J. & Strogatz, S. H. [1998] "Collective dynamics of small-world networks," *Nature* **393**, 440–442.

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