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Editorial

# Frontiers in network science: advances and applications

The notion of complex systems has gained considerable interest across disciplines when it comes to understand natural, biological, or social structures. Although physics has been concerned with well-mixed systems or dynamical systems on lattices for a long time, complex networks have emerged in the last decade as an essential framework for describing and investigating the organization of natural and living systems. A complex network can be regarded as any collection of units, or nodes, that are interacting as a system and that are connected by directed or undirected edges. In this respect, complex networks serve as natural models to describe the organization of a diverse range of systems. The investigation of complex networks has received a rapidly increasing amount of attention and the network perspective has invaded new research fields, with examples ranging from ecology and epidemiology to neuroscience, technological systems, financial markets, and socio-economics. The science of complex networks is characterized by a strong interaction among different disciplines and between theory and applications. It is a fast growing and promising area of interdisciplinary research, new applications are being developed at an ever-increasing rate.

To strengthen this field of research the program *Complex Networks as a Phenomenon across Disciplines* was announced by German VolkswagenStiftung in 2007 as part of the funding initiative *New Conceptual Approaches to Modeling and Simulation of Complex Systems*. The initiative was focused on the theory of complex networks and its main objective was the development of new methods and mathematical models to achieve at a better quantitative understanding of complexity. The initiative addressed theoreticians from a variety of scientific disciplines and allowed them to pool their expertise and to combine complementary approaches.

This topical issue of *The European Physical Journal B* (EPJB) gives a snapshot of the present status in this interdisciplinary research field. The issue contains selected research papers from participants of the International Symposium *Frontiers in Network Science* that was held in Berlin from 28-30 September, 2009. This symposium, initiated by German VolkswagenStiftung, gathered scientists working in the field of complex networks from different backgrounds and attracted more than 100 participants from all over the world. All contributions of this topical issue are original work, that were fully reviewed by independent referees, and mostly present results obtained in projects funded by the VolkswagenStiftung in the program *Complex Networks as a Phenomenon across Disciplines*. The contributions discuss and review recent advances, new perspectives, and modern techniques of network theory and their application in different natural and engineered complex systems. The main topics include methods and algorithms from different field of complex networks research, such as logistic, social, and transportation networks, as well as the complex self-organization on such systems.

One core theme of the issue is concerned with flows or transport processes on complex networks, be it the spread of opinions in social systems, material or monetary flows in logistic networks or supply chains, the transport of humans on urban or aviation networks, or trade and commodity flows on cargo shipping networks. The collected studies analyze the networked structure of these systems and study the associated dynamic processes, such as the spread of infectious diseases and invasive organisms or the spread of phase perturbation in networks of coupled oscillators, or large-scale information flows in the climate system.

As another recurrent theme, many contributions in this issue present new methods for detecting the important or relevant nodes in a given network and to distinguish these core nodes from peripheral network elements. Several techniques are proposed, ranging from structure preserving model reduction, shortest path trees, network motifs, as well as variations of Google page-rank algorithm. Finally, many contributions strive to bridge the gap between network models and real-world systems. These papers demonstrate that the framework of complex networks can be successfully applied in a rich range of

systems, ranging from business processes, coupled climate system sub-networks, the geometry of chaotic attractors, to the scientific description of recreational traffic.

This topical issue starts with a series of papers that address the structure of *Social and Economic Networks*. The first two papers investigate the problem of how to identify influential, relevant and important locations in business processes and logistic networks. The subsequent papers in this series are devoted to social network analysis, with a strong emphasis on the formation of opinions in social systems. The first two papers investigate the structure in static networks that are determined from data (i.e., the responses of participants in a business climate survey and the citation frequency in co-authorship networks). In contrast, the next paper studies the dynamic formation of a networked society where agents compete for opinions in a network of social contacts. Finally, the last study in this section relates the structure of social processes to human travel behavior, using an analysis of proxy data for leisure traffic.

These ideas emanate the next four papers, which focus more specifically on *Transportation Networks.* The first two papers in this section study human mobility on small scales, by analyzing the topology of urban road networks and the impact of human commuting for the spread of infectious diseases. The next two papers address the complexity in large-scale trade and transportation networks, by comparing the worldwide air transportation and global cargo ship movements, and in relation to the impact for the spread invasive organisms.

The two papers of the next section are devoted to develop *Complex Network Theory*, by analyzing the speed of synchronization in complex networks and large-deviation properties of the largest network component.

Finally, the last three papers are grouped into the section *New Application Areas.* These papers extend the notion of complex networks into new applications areas and fields, namely interacting climate subnetworks, the geometry of chaotic attractors using a recurrence based concept, and a production network inspired approach for simulating networked substrate-enzyme reactions.

As the guest editors of this topical issue, we hope that this selection of papers provides a good overview of the current status of complex network science and will help to promote future research activities in this exciting field.

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