Introduction to the Issue on Adaptation and Learning Over Complex Networks

THE topic of this special issue is timely and deals with a subject matter that has been receiving immense attention from various research communities, and not only within the signal processing community. Extensive research efforts on information processing over graphs exist within other fields such as statistics, computer science, optimization, control, economics, machine learning, biological sciences, and social sciences. Different fields tend to emphasize different aspects and challenges; nevertheless, opportunities for mutual cooperation are abundantly clear and the role that signal processing plays in this domain is of fundamental importance. This is because, in all these fields, there is growing interest in performing inference, learning, and optimization over graphs, such as deducing relationships from interconnections over social networks, modeling interactions among agents in biological networks, performing resource allocation distributively, passing information over networks, optimizing utility functions over graphs, adapting and learning over graphs, etc. Commonalities, and significant signal processing, run across all these applications. The articles in this special issue report on up-to-date advances in the broad area of information processing over graphs.

Two Special Issues

Due to the highly cross-disciplinary nature of complex networks, the technical articles in this April 2013 issue of the IEEE JOURNAL OF SELECTED TOPICS IN SIGNAL PROCESSING are coupled with valuable tutorial articles that appear in a second special issue, organized by the same Guest Editors, and which is published as the May 2013 issue of the *IEEE Signal Processing Magazine*. The survey articles in the magazine are meant to introduce readers to the main tools and concepts, while the more focused technical articles in J-STSP cover state-of-the-art results. Through this combination of tutorial and technical articles in both journals, readers will become better acquainted with the challenges and opportunities that the broader field of network science has to offer across the domains of information sciences, system science, computer science, social sciences, machine learning, and optimization theory. Complex networks represent a typical paradigm that helps demonstrate well how barriers among seemingly different disciplines are becoming more transparent.

Complex Networks

Self-organized and complex patterns of behavior are common in many biological networks, where no single agent is in command and yet remarkable forms of self-organization and decentralized intelligence are evident. Examples include fish joining together in schools, birds flying in formation, bees swarming towards a new hive, and bacteria diffusing towards a nutrient source. While each individual agent in these biological networks is not capable of complex behavior, it is the combined coordination among multiple agents that leads to the manifestation of sophisticated order at the network level. The study of these phenomena opens up opportunities for collaborative research across several domains in order to address and clarify several relevant questions such as how and why organized behavior arises at the group level from interactions among agents without central control; what communication topologies enable the emergence of order at the higher level from interactions at the lower level; and how information is processed during the diffusion of knowledge through the network. Several disciplines have been concerned in elucidating different aspects of these questions including evolutionary biology, animal behavior studies, physical biology, and even computer graphics. In the realm of signal processing, these questions motivate the need to study and develop decentralized strategies for information processing that are able to endow complex networks with real-time adaptation and learning abilities.

Complex networks are prevalent in modern science and their reach extends beyond biological networks. For example, these networks can help model and study how individuals are linked over social networks; they can describe the range of activities in macro-economies, or even model pathways defined over complex power grids, transportation grids, and communication grids. In many such complex systems, especially those encountered in nature, it is common for emergent behavior to arise from the interaction among individual agents, as happens with fish schooling or bird flight formations. There are ample opportunities for cross-disciplinary research in order to understand and reverse-engineer the decentralized intelligence exhibited by such networks. Although biological networks provide inspiration for the design of powerful engineered networks, the resulting theory and algorithms are applicable to a broader context including machine learning applications, distributed optimization problems, and cooperative processing over adaptive or cognitive networks.

Adaptive Networks

Adaptive networks consist of spatially distributed agents that are linked together through a connection topology. The topology may vary with time and the agents may also move. The agents cooperate with each other through local interactions and by means of in-network processing. Such networks are well-suited to perform decentralized information processing, decentralized optimization, and decentralized inference tasks. They are also well-suited to model and understand self-organized and complex behavior encountered in nature and in social and economic networks. The articles included in this

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issue cover a wide range of topics that are relevant to the study of such networks.

The guest editors would like to express their deep gratitude to the many reviewers, whose input helped improve the quality of the final articles. We are confident that readers will find this collection of articles interesting and useful. Readers are encouraged to consult the tutorial articles in the accompanying May 2013 special issue of the *IEEE Signal Processing Magazine* for additional coverage of the field.

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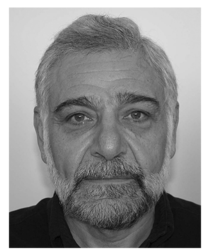

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