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Mathematical Methods and Models of Systems Interactions and Network Dynamics Special Session B17

Rossella Rizzo
University of Palermo, ITALY
Plamen Ch. Ivanov
Boston University, USA

Networks of dynamical systems exhibit complex global behaviors characterized by non-equilibrium phase transitions, self-organization and criticality, noise-induced patterns and nonlinearity, partial synchronization and desynchronization, and a variety of adaptive responses to internal and external perturbations. A fundamental question is how such collective behaviors emerge from the interplay between the dynamics of individual systems and the network topology in which the systems are embedded.

In recent years numerous investigations have focused on the mathematical properties of adaptive networks of dynamical systems to quantify the laws of time-varying and nonlinear network interactions, to uncover multiple forms of coupling and feedback loops, and to derive principles of coordination and network integration among dynamical systems in association with network states and functions.

Novel analytic and computational methods derived from applied mathematics, nonlinear dynamics, information theory, control and adaptive networks theory as well as high-dimensional network modeling approaches were recently developed to build an adequate theoretical framework and explore how hierarchical organization in network structure (sub-networks and modules) relates to multi-stability and meta-stability of dynamic states with emergent global functions.

While these advances have a broad spectrum of applications to physical, biological, ecological and social systems, investigations of the temporal complexity and emergent global behaviors in adaptive networks of dynamical systems lay the foundation of a new theoretical framework to study living systems. Of particular relevance to physiology and medicine is how physiological systems, processes and functions can be mathematically described and studied within the context of complex networks dynamics.

A new field, Network Physiology, has emerged to address the fundamental question of how physiological systems and sub-systems continuously coordinate, synchronize, and integrate their dynamics as a network to optimize functions and to maintain health. In addition to the traditional approach in biology and physiology that defines health and disease through structural, dynamic, and regulatory changes in individual systems, the new conceptual framework of Network Physiology focuses on the coordination and network interactions among systems as a hallmark of physiological state and function. This poses new challenges in developing generalized methodology adequate to quantify complex dynamics of networks where nodes represent diverse dynamical systems with distinct forms of coupling that continuously change in time.

Novel methods are needed to provide insights into physiological structure and function in health and disease, and across levels of integration from genomic interactions to inter-cellular signaling and metabolic networks, to communications among integrated organ systems.

This special session will provide a venue for leading experts to present and discuss recent advances in the theory of adaptive networks of dynamical systems and their applications to physiology and medicine, as well as to outline key questions and future directions of research aimed to uncover the relations of network topology and dynamics with emerging physiological states and functions in health and disease. This session is scheduled on July $25^{th} - 26^{th}$.

E–mail: rossella.rizzo@unipa.it.