Scientia Iranica D (2021) 28(3), 1535–1538

Sharif University of Technology
Scientia Iranica
Transactions D: Computer Science & Engineering and Electrical Engineering
http://scientiairanica.sharif.edu

Guest editorial: Special issue on collective behavior of nonlinear dynamical networks

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Collective behaviors of dynamical networks are the focus of intense research in various fields of science [1,2]. Dynamical networks can be considered as populations of interacting nonlinear systems from which complex spatiotemporal patterns can emerge [3–5]. For instance, one of such emerging patterns is synchronization, which refers to the strongest form of network cooperative dynamics [6,7]. Each individual in the network tends to share common rhythms and the same dynamical behavior in the synchronization state [8]. The emergence of the traveling and propagating waves, especially spiral waves, is another example of fascinating collective behaviors of dynamical networks [9]. The other important examples are associated with the simultaneous coexistence of both incoherent and coherent states in networks, which is called chimera state [10,11].

Various studies in the literature have investigated the mechanism of appearance of collective behavior in dynamical networks, numerically and analytically [12–15]. Generally, they have pointed out three main factors in the emergence of collective behaviors [16,17]: 1) the dynamics of the individual system in each node, 2) the coupling type and strength, and 3) the topology of the network. Different types of complex nonlinear systems can be located in each network node, such as systems expressed by ordinary differential (or difference) equations [18] and fractional-order systems [19–21]. Finding the proper coupling strength that regulates the interactions of dynamical networks is another important point in this field of research [22,23]. The structure of a network can also affect the functions of emerging collective behaviors [24]. The dynamical networks can be identical or non-identical [25], weighted or unweighted [26], directed or undirected [27], time-varying [28,29] or fixed in different types of topologies such as regular, random [30], scale-free [31,32], small-world [33], etc. Many recent hot topics are related to collective behavior of nonlinear dynamical networks. Some examples are "resilience indicators of complex networks" [34], "multilayer and multiplex networks" [35,36], "coherence resonance" [37,38], "explosive synchronization" [39,40], "cluster synchronization" [41,42], "chimera states in networks" [43,44], "wave propagation in networks" [45], and "spiral waves in networks" [46,47].

This mini special issue reviews the current state of the art in the research on collective behaviors of the dynamical networks, which is the key factor in reaching more accurate network models as well as enriching our knowledge about the function of the natural networks. In [48], the authors investigated the slowness in ischemic stroke patients. A Trier Social Stress Test (TSST) is used to reveal the slowness of the biological system. The slowness of dynamics is calculated for the ECG of healthy individuals and patients with ischemic stroke. Ten healthy individuals and nine ischemic stroke patients are studied. Six early warning indicators based on slowness and variability are used in this study. The indicators are applied to the RR interval of individuals in four stages. Heart rate variations are studied as another measure of slowness for the dynamics. The results reveal that there is no significant difference in the slowness of healthy and patient cases.

In [49], the authors considered the network of Lorenz systems with time-varying links to study synchronization and chimera patterns. It is assumed that the non-local connections of the network are switched on/off with a specified period, while the local links are fixed. The ratio of time of on to off links is called the discontinuity rate. They investigated the network for different periods and discontinuity rates analytically and numerically. They reported a new pattern called intermittent transient chimera in which the chimera and the synchronization changed alternatively in time. The results show that when the continuous links change to switching, the coupling strength needed for synchronization increases. Furthermore, as the discontinuity rate decreases, the region for observing chimeras is enlarged.

The authors in [50] introduced an adaptive coupling for the network of randomly coupled Kuramoto-Sakaguchi oscillators. The adaptive coupling allows for incorporation of the dynamics of the oscillators in the strength of connections. They reported the emergence of several synchronized, cluster synchronized, and partial synchronized patterns relying on the coupling. The effect of the random delusion of the links was also investigated. The results indicated that as the number of links decreased, the incoherency increased in the network. However, the authors found some sparse topologies which point to stable in-phase synchronization.

A modified Fitzhugh and Rinzel neuron model was proposed in [51] upon introducing the magnetic flux variable. The authors analyzed the stability of the novel model by calculating the equilibrium points in the presence and absence of electromagnetic induction. Furthermore, the bifurcation diagrams and the Lyapunov exponents were derived and it was shown that the model was multi-stable and could exhibit diverse firing patterns. The authors also investigated the effects of coupling strength as well as the frequency and amplitude of the external stimuli on the behaviors of a two-dimensional network of the proposed model. They compared wave propagation in the network with and without electromagnetic induction.

Thus, this special issue provides a brief perspective of current research on the collective behavior of dynamical networks and we hope that the related researchers in this field find it useful. We wish to express our appreciation to the authors of all the papers in this special issue for the excellent contributions as well as the reviewers for their high-quality work on reviewing the manuscripts.

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