Collective Behaviors in Complex Networks

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Abstract

Complex networks connecting similar, if not identical, dynamical systems are very common in physics, biology, economics, and social sciences. Such networks are often characterized by the emergence of self-organized **collective behaviors**. Ecological networks provide compelling examples, with evolutionary adaptations often promoting such self-organization. Here we provide an overview of a number of studies concerning the dynamics of population networks. Instead of presenting these studies in detail, we focus on how these highlight and illustrate the main collective behaviors that commonly arise in self-organized complex networks. In particular, we will show series of images or animations to emphasize the universality of network-wide **synchronization** dynamics and **pattern formation**. These phenomena are among the most fascinating collective behaviors observed in the natural and social world, and can often be explained and understood in terms of cross-disciplinarily applicable and intuitively compelling dynamical mechanisms.

Collective behaviors

In many animal and plant populations composed of identical or very similar individuals collective behaviors can be often observed. Birds (see left), fish (see right), and insects (ants, bees,…) are typical examples. The emergence of these behaviors can be explained through basic evolutionary principles. Similar self-organized structures are also present in our societies.

Synchronization

The most simple and strong form of collective behavior is synchrony, which can be complete (see left) or almost complete (see right). Synchronization of identical or similar systems is due to the presence of a common exogenous input and/or to the communication among the systems. Weak forms of synchronization, such as recurrent and cluster synchronization, are also observed in nature.

Pattern formation

When the individuals or cells of a network are synchronized in clusters and the dynamic behavior of each synchronized cluster tends toward a stable equilibrium the result is the emergence of a spatial pattern. Insects (see left) and mammals (see right) often display spots or stripes which can be justified from evolutionary principles (e.g., anti-predator or mimicry).

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