Modeling Systems with Coupled Dynamics (SCDs): A Multi-Agent, Networks, and Game Theory-based Approach

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Abstract

The coupling and coordination of competing elements in a system have been studied. Notions such as the Mixed-strategy Nash equilibrium (MSNE) is a commonly-used solution in game theoretic models (Cobb and Sen, 2014). Also, it has been established that natural dynamics are leading to a particular system equilibrium or coordination, according to the players' interactions.

In this regard, research on the connectivity and interdependence of coupled systems is a crucial subject to understand the interactions between two o more systems, in which the dynamics and even the structure, of one system, can depend on another (Wider et al., 2016).

Concerning systems with coupled dynamics, it is well-recognized that interaction among systems can exhibit dynamical and emergent properties. Nevertheless, representing and modeling these aspects is not trivial.

In this context, this work develops an abstract modeling proposal of Systems with Coupled Dynamics (SCDs). Our objective is to present a viewpoint on how network, game, and multi-agent theories can be used to represent and assess the interactions between and within SCDs. We provide an overview of knowledge and gaps in the literature regarding networks (Newman et al., 2006), game theory (Siegel, 2013), and multi-agent systems (Gershenson, 2002; Gilbert and Conte, 1995), as well as instances where they have been combined successfully, *e.g.* Santos et al. (2006). We generalize an approach for the assessment of multi-system interactions and flows. We also provide a design framework and the evaluation of a SCD.

Based on our notions and formalizations, the study of several dynamics of natural systems can be possible. A starting point for the application of our approach is the representation of the dynamics of competitive sports. In this way, we consider soccer as an example of SDCs that by means our approach can be studied. Preliminary results from sports motivate us to study applications in biological systems, such as regulatory protein networks analyzed as SDCs.

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