A novel framework to capture the coevolution of opinions and decisions in complex networks

Zino, Lorenzo; Ye, Mengbin ; Cao, Ming

A novel framework to capture the coevolution of opinions and decisions in complex networks*

Lorenzo Zino[1], Mengbin Ye[2,1], and Ming Cao[1]
[1]University of Groningen, Groningen, The Netherlands [2]Curtin University, Perth, Australia

In the last decades, mathematical models have been widely adopted to represent and study complex behaviors in social systems[1]. We focus on the emergent behavior of a social network whose members dynamically interact, revising their opinion and taking collective decisions. Surprisingly, despite an evident interdependence between these two social dynamics and the key role that they have in our society, few have been the efforts to develop a unified mathematical framework that captures such a coevolution.

Motivated by these preliminary efforts[2,3], we propose a novel mathematical framework at the interface between opinion dynamics[4] and evolutionary game theory[5], in which individuals simultaneously update their opinions and revise their actions on a two-layer network structure, under the effect of information on the others' opinions shared on a *communication layer*, and observation of the others' actions on an *influence layer*. Specifically, one randomly selected individual, at each time-step, updates his or her opinion by averaging it with those shared by peers on the communication layer and, due to *susceptibility*, to the actions observed on the influence layer. Simultaneously, the individual also decides to take an action, under social pressure to conform with others' actions observed on the influence layer, and in view of his or her *commitment* to his or her own opinion, as illustrated by the schematic in Fig. 1(a).

We present a real-world application of the proposed framework by tailoring it to represent introduction of an advantageous innovation. The model is able to reproduce various real-world phenomena[6]: the persistent rejection of the innovation and popularity of disadvantageous status quo, the emergence of unpopular norms, and the occurrence of paradigm shifts toward adoption of the innovation. Through rigorous analyses and extensive campaigns of Monte Carlo simulations, we illuminate the effect of *susceptibility* and *commitment* and on the key role played by the network topology on the emergent behavior of the social system, thereby identifying three different regimes corresponding to the three real-world phenomena described above (in Fig. 1(b)). The phase transitions between the regimes is nontrivially shaped by the network topology, whereby structures that seem to favor the occurrence of paradigm shifts when individuals have small susceptibility to the others' action (e.g., small-world networks), show instead strong inertia as the susceptibility increases, hindering the spread of innovation and favoring the emergence of (popular or unpopular) disadvantageous norms (see Fig. 1(c)).

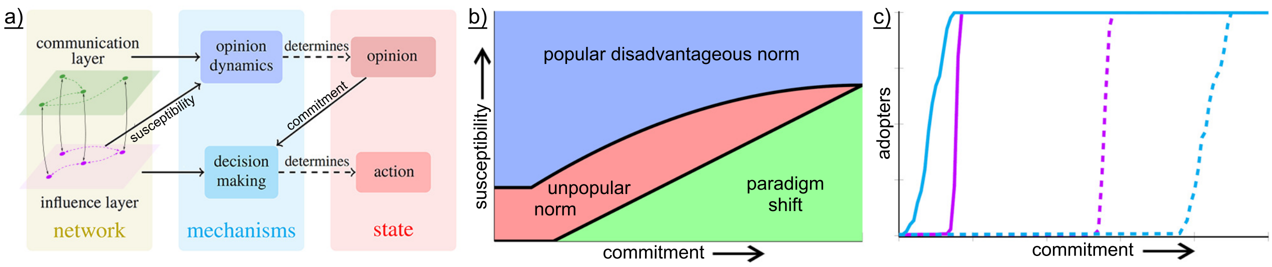

Figure 1: Panel (a) shows a schematic of the coupled evolution of opinions and actions. Panel (b) shows the phase transition between the three regimes on the parameter space for a regular random graph. Panel (c) shows Monte Carlo estimations of the number of adopters of the innovation for increasing levels of commitment on a regular (violet) and a small-world (cyan) network. The solid (dashed) curves have small (large) susceptibility.

References: [1] Castellano et al., *Rev.Mod.Phys.* 81 (2009). [2] F. Gargiulo and J.J. Ramasco, *PloS One* 7 (2012). [3] M. Ye et al., *Automatica*, 107 (2019). [4] A.V. Proskurnikov and R. Tempo, *Ann.Rev.Control* 43 (2017). [5] H.P. Young, *PNAS* 108 (2011). [6] D. Centola et al., *Am.J.Sociology* 110 (2005).

* This work was supported in part by the European Research Council (ERC-CoG-771687) and the Netherlands Organization for Scientific Research (NWO-vidi-14134).