**Title:** Leveraging Social Contagion to Foster Consensus in Collective Decision-Making

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**Abstract:** Appropriate social transfer of information among units of a multi-agent system (MAS) is a prerequisite for an effective collective response to changing environmental conditions. From the network perspective, this social information transfer requires understanding the interplay between network topology and agents’ dynamics [1]. Specifically, information propagation through the MAS can either take the form of a simple contagion—associated with pairwise interactions—or a complex contagion—involving social influence and reinforcement [2, 3].

The key role played by the network topology in this social information transfer has been acknowledged [1]. In that work, a nontrivial relationship between the pace of external perturbations and the network degree is reported. Subsequently, Horsevad et al. [2] revealed the possibility of complex contagion with a leader-follower consensus model of distributed decision-making lacking thresholds and/or nonlinearities. Prior to that work, complex contagions were limited to decision-making models based on a binary decision variable with a threshold [3]. Reference [2] highlights that other network properties, beyond the degree distribution, influence the social contagion process. The existence of a transition from a simple contagion to a complex one hinges on knowing which network property plays a key role.

One serious limitation of these works is the lack of a systematic way of characterizing the type of social contagion for a given collective decision-making protocol. What has been found true for the first-order leader-follower consensus might not hold for other forms of distributed decision-making. For instance, the Kirchhoff index and clustering coefficient may not be the appropriate metrics to decipher which type of social contagion is unfolding. It is worth stressing that these network metrics only incorporate features of the network topology without accounting for the agents’ dynamics taking place over this network. Here, we propose a novel approach based on spectral graph theory to address this issue by considering a generalized metric that would embody network topology along with agents’ dynamics. Specifically, the spectrum of the graph Laplacian offers valuable information about both network structure and agents’ dynamics. The eigenvalues of the Laplacian matrix have been used for community detection and spectral clustering. As a matter of fact, the spectrum of the graph Laplacian can reveal information about both global and local properties of the network, such as the number of connected components, clustering coefficient, and spectral gap, etc. Furthermore, the Kirchhoff index can be expressed as the sum of the inverse of the eigenvalues. Also, different parts of the spectrum can be associated with community structures, motif multiplication, and bipartiteness of the network graph. This approach has the potential to extend our results to any collective decision-making protocol beyond the simple leader-follower consensus.

References

1. Mateo, D., Horsevad, N., Hassani, V., Chamanbaz, M., & Bouffanais, R. (2019). Optimal network topology for responsive collective behavior. *Science Advances*, **5**(4), eaau0999.
2. Horsevad, N., Mateo, D., Kooij, R. E., Barrat, A., & Bouffanais, R. (2022). Transition from simple to complex contagion in collective decision-making. *Nature Communications*, **13**(1), 1442.
3. Centola, D., Eguíluz, V. M., & Macy, M. W. (2007). Cascade dynamics of complex propagation. *Physica A: Statistical Mechanics and its Applications*, **374**(1), 449-456.

**Keywords**: Collective decision-making, Social contagion, Distributed consensus.

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