Stability in Flux: Group Dynamics in Evolving Networks

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Extended Abstract

From Facebook groups and online gaming clans, to social movements and terrorist cells, groups of individuals aligned by interest, values or background are of increasing interest to social network researchers (Snow et al., 1980; Zheleva et al., 2009). In particular, understanding the structural and dynamic factors that influence the evolution of these groups remains an open challenge (Palla et al., 2007; Geard and Bullock, 2008, 2010). Why do some groups persist and succeed, while others fail to do so?

Three features characterise real social networks. They are inherently dynamic: explaining the structure of social networks requires us to understand how this structure is created, modified and maintained. They are co-evolutionary, exhibiting a reflexive relationship between topology and state. For example, individuals often interact preferentially with others who are similar to themselves, thus state affects topology; at the same time, neighbouring individuals tend to influence one another and hence become more similar, thus topology affects state (Gross and Blasius, 2008). Finally, interactions between individuals are not distributed uniformly across a network: rather, we can detect community structure, in which subsets of individuals are more densely linked to each other than to the rest of the population (Newman, 2006).

Analysis of telephone and collaboration data by Palla et al. (2007) has demonstrated some of the ways in which social groups evolve over time, but there is more to be done in understanding the multi-level relationship between individual and group dynamics. Here, we address two questions: How do stable macro-level structures and behaviours emerge and persist as a consequence of simple micro-level processes? How can we characterise the dynamics of meso-level structures such as groups and communities?

We introduce a simple model of a co-evolving network in which the state of an individual represents the group to which it is currently (and exclusively) affiliated. Four processes govern network evolution: individuals can create new groups, influence neighbours to switch affiliation to their group, replace an out-group edge with an in-group edge, or replace edges at random.

Using this model, we explore the parameter space defined by the relative rates of each process, revealing a region in which networks exhibit connected community structure reminiscent of observed social networks (Figure 1). We demonstrate how macro-level properties of the network (e.g., state and degree distribution, modularity, clustering coefficient and path length) stabilise, while underlying micro- and meso-level properties remain dynamic; that is, individuals continue to update their neighbours and states, and groups are born, grow, shrink and die.

Finally, we report findings on the behaviour of groups: at equilibrium, there is a stable rank-distribution of group sizes; however, the identities of the groups occupying each rank change over time. Furthermore, the distribution of group lifespans is bimodal, reflecting two possible group trajectories: After being introduced into a population, a group either thrives, or struggles. Interestingly, the probability of these two events appears to be almost entirely stochastic, and appears to be independent of factors that one might expect play a role, such as the location of group foundation.

While our model is undoubtedly simple, we believe it provides a useful baseline for further studies, and a helpful tool for understanding the multi-level dynamic interactions that underlie the complex behaviour of more complicated models.

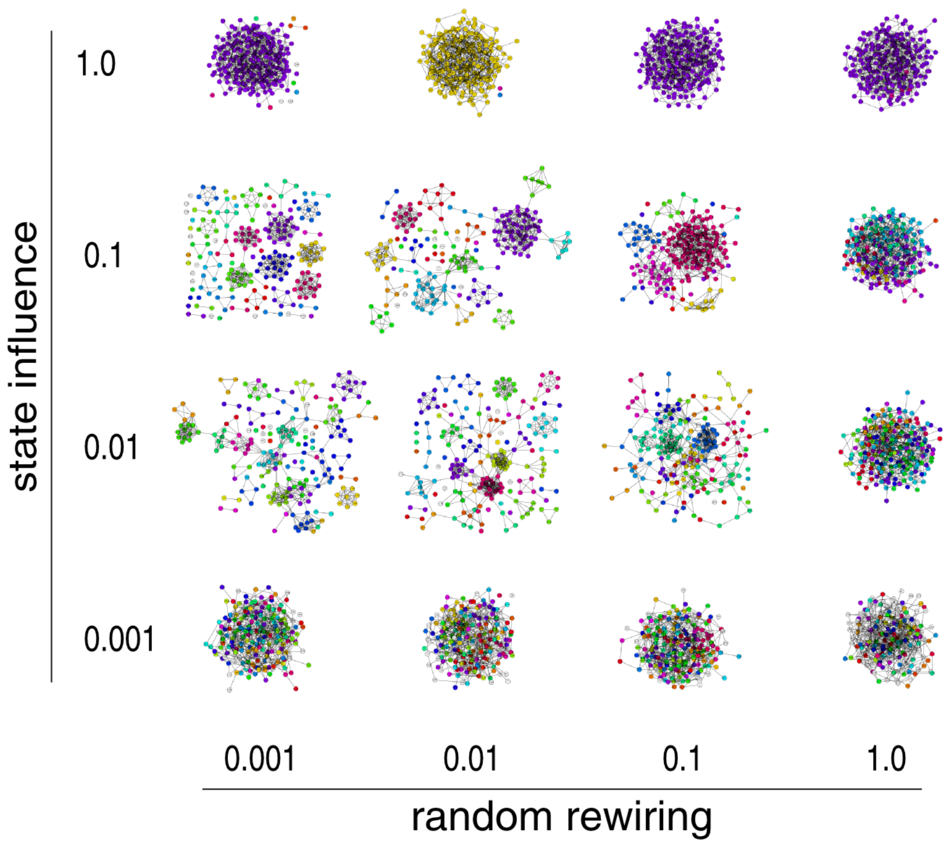

Figure 1: A slice through model parameter space, showing sample networks that result from different rates of state influence (y-axis) and random rewiring (x-axis), given fixed rates of group rewiring (1.0) and state innovation (0.001). When state influence is very high (top row), a single group spreads to dominate the population. In contrast, when state influence is very low (bottom row), groups grow very slowly, if at all, and many small groups coexist. When random rewiring is very high (right column), little structure emerges in the population. Lower levels of random rewiring enable the emergence of topological communities focused around shared state. These communities either disconnect completely, fragmenting the population and inhibiting the flow of individuals between groups, or remain connected (the central region). Note that these networks are static snapshots: while aggregate network properties stabilise, local properties such as the pattern of social ties and distribution of groups continue to evolve dynamically.

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