Detecting Political Secession of Fragmented Communities in Social Networks via Deep Link Entropy Method

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Abstract
Breakdown of global connectivity in social networks trough disintegration of fragmented but interacting communities leading to political secession is a major source of forming and strengthening echo chambers and political polarization. Hence, quantifying the significance of each edge (the connection or relationship between two particular nodes, for example two friends on Facebook, or two follower/followed accounts in Instagram or Twitter) from the perspective of global connectivity is a crucial problem in online political communication studies. Among the existing methods for quantifying the edge significance in complex social networks, link entropy (LE) has been a very successful one, which takes into account the two nodes' (making up that particular edge) uncertainties of belonging to different communities. Considering also the contribution of the uncertainties of the adjacent nodes of those two particular nodes, we recently proposed the deep link entropy (DLE) method. In this work, we examine the political secession of disintegrating communities. In particular, we study complex social networks consisting of multiple communities which are in direct or indirect interaction through bridging individuals. We consider scenarios where those bridges are lost through unfollowing or unfriending an individual belonging to a different community. We show that the DLE method detects the community disintegration with a high performance. We discuss DLE method's contribution to social network and online political communication studies, in particular to examining the online political secession.

Keywords: Deliberative Enclaves, Fragmentation, Turkish Politics, Youth Participation in Politics, Social Media, Twitter

Introduction

Social networks consist of ideologically fragmented communities, and the strength of interaction between each pair of communities play an essential role in the dynamics of echo chambers and polarization. Data driven social network analyses are fruitful for a better understanding of these dynamics. Sloan et al. (2015) showed that it is possible to characteristics from tweets. Studying the anti-migrant sentiments, it was recently shown that among the fragmented groups, even the similar minded groups are fragmented (Yurtcicek Ozaydin 2018). Deliberative enclaves (Yurtcicek Ozaydin 2019) and strong echo chambers (Yurtcicek Ozaydin and Nishida 2021) are found among the youth groups of political parties on Twitter. Jo et al. (2021) studied the spread of coronavirus and policy implications based on social network analysis. Analyzing hashtag wars in geographical basis, it was found that similar to presential or general elections, local elections too contribute to political polarization across a nation (Yurtcicek Ozaydin 2020; 2021).

In addition to live or historical data such as tweets or posts, the more precisely analyzing the dynamics of social network structure paves the way for a more accurate understanding of the echo chambers and political polarization. The structure is determined by the peers and their connections. We consider each peer of a social network as a node, n_i and the connection between two nodes n_i and n_j as an edge, e_{i-j}. See Figure 1 for illustrating example where $i = 3$ and $j = 9$.

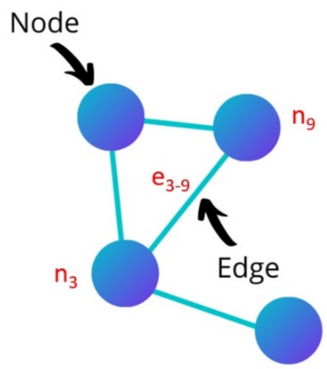

Figure 1: Edge e_{3-9} is connecting nodes n_3 and n_9.

The impact of establishing a new edge or breaking of an existing edge on the echo chamber and polarization dynamics of the communities of a network heavily depends on the properties of the nodes of that edge. If its nodes belong to the same community, the impact might be limited. However, if its nodes are constituting a bridge between two communities, i.e. n_i belongs to one community and n_j to another community, the impact might be greater in the sense that, breaking that edge will interrupt the interaction between communities, while establishing such an edge improves the interaction. Hence, the significance of each edge from the viewpoint of diffusion of ideologies and global connection provides a valuable information about the echo chamber and polarization dynamics of the fragmented communities. See Figure 2 for example. Edges in red color, for example e_{4-10} and e_{13-24} are expected to be more significant than edges in blue color, for example e_{1-2} and e_{9-12}. Quantifying the significance of each edge is therefore important in analyzing the network structure and several methods have been proposed for calculating the significance, the most popular ones being bridgeness (Cheng et al., 2010), k-path centrality (De Meo et al., 2012), degree product (Wang and Chen, 2008) and edge betweenness centrality (Girvan and Newman, 2002). Qian et al. (2017) have proposed the Link Entropy (LE) method, based on the entropies of the nodes, which outperforms the existing methods, and we recently proposed the Deep Link Entropy method, as an improvement over LE by also considering the entropies of adjacent nodes of the pair of nodes in hand (Yurtcicek Ozaydin and Ozaydin, 2021).

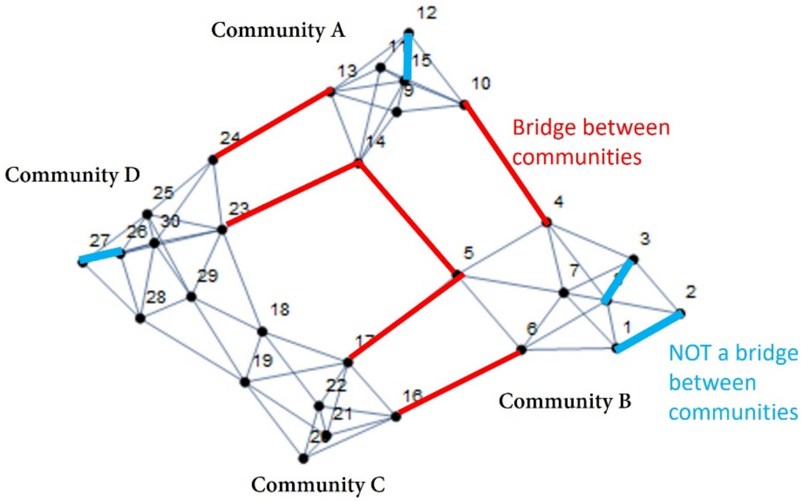

Figure 2: Edges (in red) connecting two fragmented communities are more significant than edges (blue) connecting nodes of within a community.

In both LE and DLE methods, the first step is to discover the communities by applying the non-negative matrix factorization method (Wang et al, 2011). Because communities are not isolated (disconnected) from each other so that nodes might be connected to nodes of more than one community, each node in a complex social network is found to be a member of each community with some probability. In other words, there is a finite uncertainty for each node to be belonging to each community. Based on these uncertainties, particular entropy functions are calculated. In details, for calculating the significance of an edge e_{i-j} LE calculates the entropies $H(n_i)$ and $H(n_j)$ of n_i and n_j, respectively, and $JSD(n_i, n_j)$ the Jensen-Shannon divergence of n_i and n_j. In DLE, entropies of the adjacent nodes of n_i and n_j are also calculated and added with a weight. See Yurtcicek Ozaydin and Ozaydin (2021), for details. Although our focus is on social networks within the context of online political communications, edge significance is important in a wider context, such as in quantum networks (Ozaydin et al. 2014; Li et al. 2016; Zang et al. 2016; Bugu et al. 2020; Ozaydin et al. 2021).

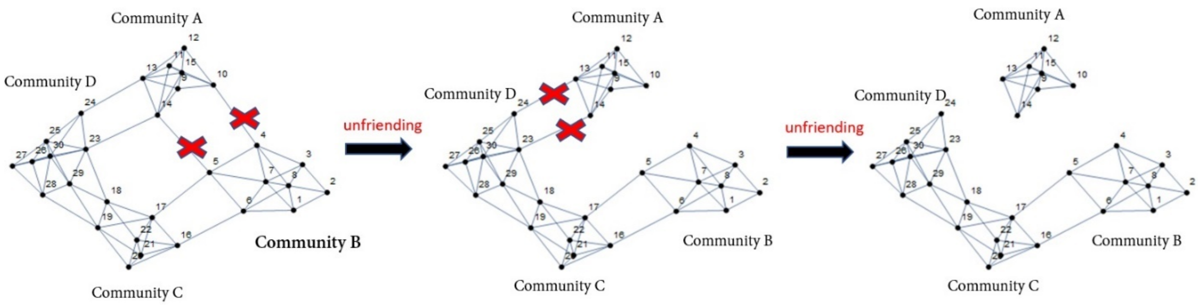

Figure 3: Breaking of edges e_{4-10} and e_{5-14} through *unfriending* or *unfollowing* in a social network site, political secession of Communities A and B is observed. Furthermore, if edges e_{13-24} and e_{14-23} are also broken, Community A is disintegrated from the other communities.

In the online political communication studies, disintegration of communities from each other is widely studied. However, interrupting the interaction between two communities can also occur due to secession of them. See Figure 3 for the illustration. At the two extremes, Community A is either connected to Communities B and D (left), or it is disintegrated from all the communities (right). However in a moderate case, Community A lost its connections only with Community B. They can still interact through other communities, though being very limited. We refer to such a case as political secession.

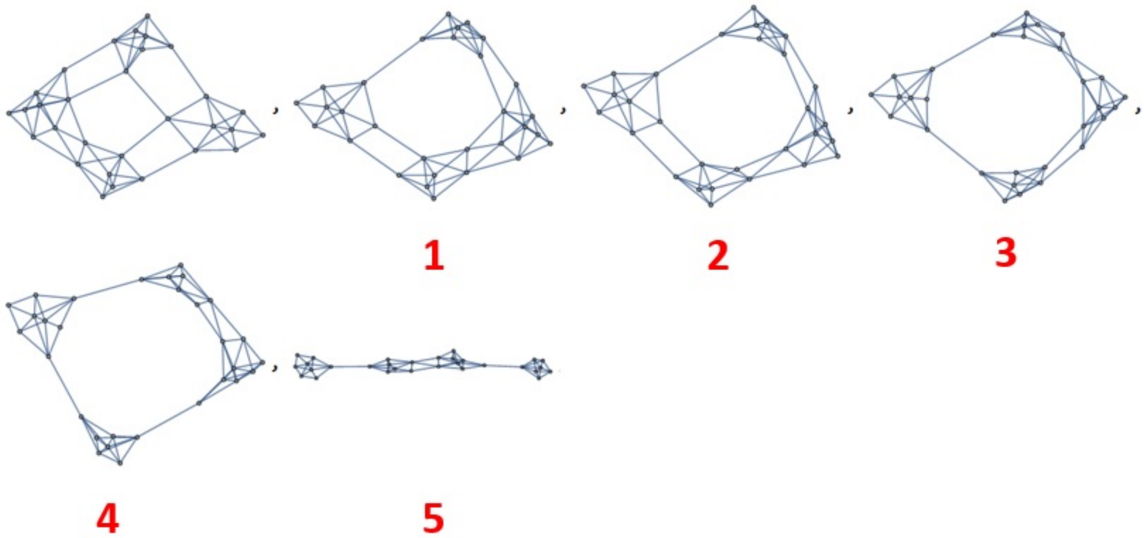

Figure 4: Observing secession according to LE method.

We examine the political secession of communities in complex networks using LE and DLE methods, as follows. After quantifying the significance of each edge, according to each method, the top significant edge is removed. The community discovery algorithm is repeated because in each edge-removal, the network structure is slightly changed. The significance of all the remaining edges are calculated again, and the top significant edge is removed. This procedure is repeated until all the edges are removed. We find that DLE successfully leads to secession, earlier than LE. As an example, we present the results on the social network illustrated in Figure 2. As can be seen in Figure 4, applying LE, we find that the first secession is observed in 5 steps, i.e. after removing 5 edges. However, applying DLE as can be seen in Figure 5, secession is observed in only 2 steps, i.e. after removing 2 edges, only.

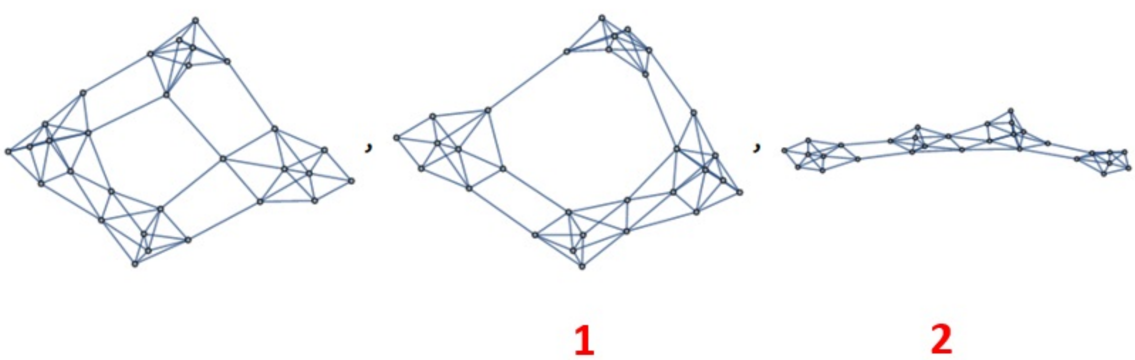

Figure 5: Observing secession according to DLE method.

Conclusions

We have examined the political secession of fragmentation of communities in social networks using the edge significance quantification in literature, namely Link Entropy, and Deep Link Entropy. The latter one is an improvement over the former by considering the adjacent nodes, enabling a deeper insight. We find that through such a consideration, political secession is observed faster. We point to the need of developing a detection mechanism specific for political secession as an open question for further research. We also argue that political secession deserves more attraction in online political communication studies, in particular in political fragmentation, echo chambers and polarization.

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