STRUCTURAL BALANCE DYNAMICS IN INSURGENT NETWORKS

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Summary

Relationships between actors in complex, multi-agent conflicts can be difficult to explain and predict. We propose a model for connectivity dynamics in the Syrian militant network that hybridizes the influence of individual state actors and balancing forces generated by the network's global structure. Models such as these could be used to predict future battles in an ongoing conflict or to develop control strategies to obtain desired outcomes.

Introduction

International conflicts can be characterized as signed networks with dynamics on the edges which represent relationships between conflict participants. A particular edge in a conflict may be explained by the attributes and past interactions of the two nodes that the edge connects. Oftentimes, however, information about individual diads is insufficient to explain their connection as the global structure of the network also exerts a force on individual ties. One such force that has been found in many signed social networks is structural balance [5, 6, 2]. We explore the influence of node attributes and balancing forces on edge dynamics in the Syrian militant network and construct a model for tie formation in this conflict. Models such as these can be used to identify how different forces in the network interact to determine edge states as well as to predict future alliances and battles in complex ongoing conflicts with many agents.

Methods and Results

The Syrian militant network consists of 37 distinct militant groups each with a number of attributes such as ideology, group size, and external state sponsorship [4, 3]. Previous studies have found that ideology is the best predictor of fighting in the Syrian militant network while power differentials between groups is the second best of the proposed predictors [4]. We wish to create a model that anticipates the signs of ties in the network over time and

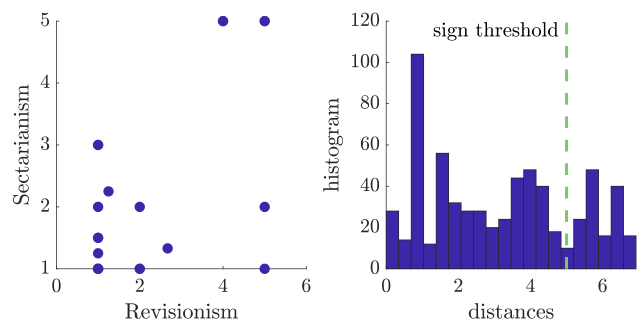

Figure 1: (a) Militant groups have ideologies that vary along multiple dimensions. (b) Network edges are predicted by setting a threshold on the ideological distances distribution. Over this threshold ties are predicted to be negative.

so begin by using ideological distances between groups to generate tie sign predictions. Ideology is measured along three dimensions — sectarianism, salafism, and revisionism [4]. We take the distribution of distances between nodes in ideological space and set a threshold over which ties should transition from positive to negative, Fig. 1. This model predicts many network signs Fig. 2, however, there are still many incorrectly predicted signs and certain ties change sign over time, which is not a phenomena that would be predicted by node attributes that are stable, such as ideology.

A force that appears in social networks that could account for sign changes is structural balance. Structural balance theory asserts that nodes in certain networks desire consistent, balanced relationships amongst themselves, compelling edges to shift in order to eliminate imbalanced triads in a network [1, 5, 7, 2]. We find significant levels of both strong and weak structural balanced in our network compared with null models, as defined in previous studies [5, 2]. Since it appears our network may be under the influence of balancing forces, we subject our ideologically predicted network to both strong and weak structural

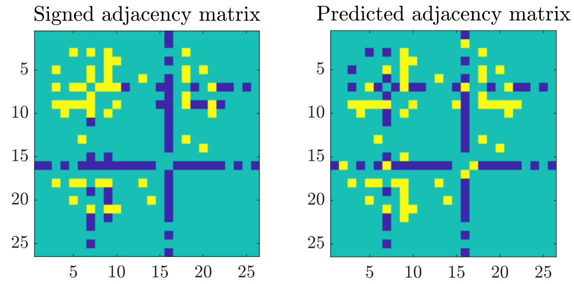

Figure 2: Tie signs in conflict compared to those predicted by the ideological model.

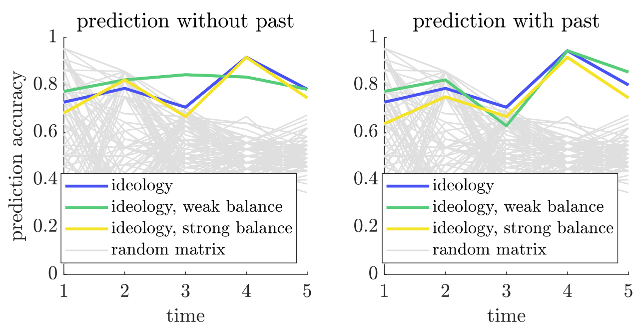

Figure 3: Tie sign prediction accuracy over time for models compared with null models. (a) Models generated with ideological distances combined with strong and weak balance. (b) Models that additionally incorporate past network states to predict future states.

balance dynamics in order to improve the balance in our model and therefore improve edge predictions. Previous studies have proposed dynamics for strong structural balance [6]. We modify this dynamical system to describe weak balance dynamics as well.

Let $\boldsymbol{X}$ be the signed adjacency matrix and $\boldsymbol{P} = \boldsymbol{X} > 0$.

$$\text{Strong balance} \quad \frac{d\boldsymbol{X}}{dt} = \boldsymbol{X}^2 \tag{1}$$

$$\text{Weak balance} \quad \frac{d\boldsymbol{X}}{dt} = \frac{1}{2}(\boldsymbol{X}\boldsymbol{P} + \boldsymbol{P}\boldsymbol{X}) \tag{2}$$

By subjecting the ideologically predicted network to balancing forces, unbalanced edges are modified to bring the network into a more holistically balanced state which can improve edge predictions, Fig. 3. Weak balance, but not strong structural balance, on average improves the prediction accuracy of ideologically generated prediction models. This effect is more significant when past states are not used to inform current states.

Weak structural balance theory predicts that no strongly imbalanced triads should exist in a social network. Our

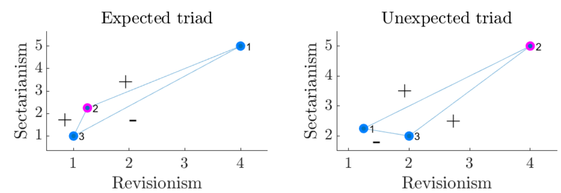

Figure 4: A strongly imbalanced triad predicted by our model compared with a triad not predicted by our model.

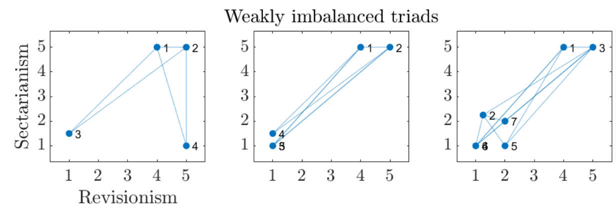

Figure 5: Weakly imbalanced structures present in network over time.

model suggests, however, that with the additional influence of ideological forces, some strongly imbalanced triads should be expected to persist. Our model allows us to differentiate between expected and unexpected strongly unbalanced triads and target unexpected network substructures for further analysis as shown in Fig. 4. We use our model also to differentiate between expected and unexpected weakly imbalanced triads and find that certain key nodes in the network are responsible for generating all unexpected weakly imbalanced structures, Fig 5. Such analysis allows us to identify subsets of the network that may not be subject to the proposed dynamics due, potentially, to differences in power or external state sponsors.

Discussion

Modeling the Syrian militant network with both node attributes and balancing forces allows us to understand how multiple forces interact to generate the edge signs observed in the data. We can use such models to predict how different control procedures, such as shifting ideologies, or inserting imbalanced triads, would percolate through the network over time, changing its future structure. Potentially important node features, such as power, and edge features, such as weights, are not currently considered; inclusion of these factors may improve the model.

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