Inferring Signed Networks From Contact Patterns

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In network science, the object of analysis is often not directly observable. One needs to reconstruct the network of interest from observations to make analysis possible. Here, we consider the problem of reconstructing signed social relationships, i.e., determine the signed network A of positive and negative relationships between individuals based on a contact matrix X, containing counts of pairwise observed interactions.

Existing methods range from simple regression models that predict individual links to more elaborate models that reconstruct the network as a whole. While these methods have their advantages, they often suffer from two intertwined systematic problems. First, most methods cannot distinguish between the absence of a relationship and the presence of an actual negative tie as both result in a lack of observed interaction. This leads to a second problem: negative edges are overrepresented because absent interactions are usually interpreted as negative relationships between individuals. We address these issues by modeling social interaction groups that help us determine whether or not a lack of interaction occurs due to a lack of opportunity to do so.

Our generative model depends on two principles. First, people only interact with each other if they have a "chance" to do so. We model this opportunity by assigning each node i to an interaction group g_ℓ. Interactions are only permitted between pairs of individuals during an observation period if they are assigned to the same group. Second, we assume that the number of interactions, X_{ij} between a pair of individuals, i and j, follows a binomial distribution with probability p_{sign}) that depends on their relationship:

$$p_{\text{sign}} = \begin{cases} p^+ & \text{if } A_{ij} = +1 \\ p^- & \text{if } A_{ij} = -1 \\ p^0 & \text{if } A_{ij} = 0 \end{cases}, \tag{1}$$

where $p^+ > p^0 > p^-$, such that positive relationships result in more interactions and negative relationships result in less interactions. We present an efficient Markov chain Monte Carlo algorithm to perform Bayesian inference and reliably estimate the set of signed relationships and the social interaction groups over time.

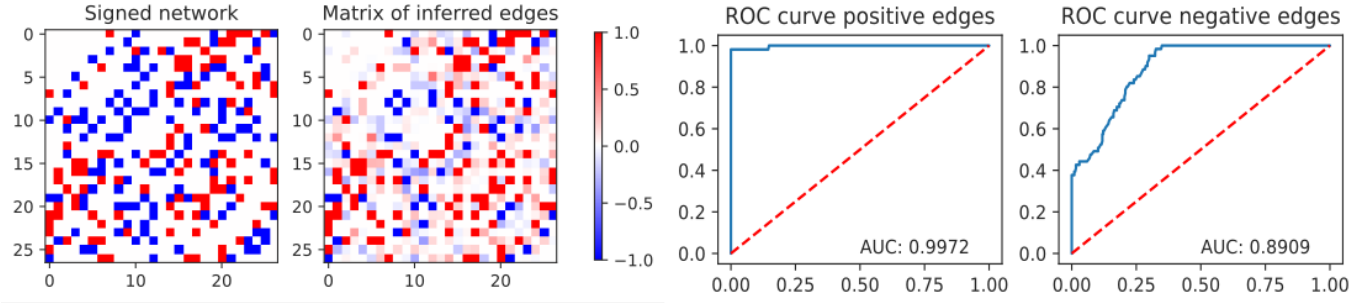

Figure 1: On the left, we can see the adjacency matrix of a signed network and the mean of a sample we drew from the posterior distribution of the signed network using our Bayesian inference algorithm. On the right, we can see the corresponding ROC curves displaying the accuracy of our inferences. We can find the corresponding AUC values the graphs as well.

[1] Neal, J. W., Neal, Z. P., Durbin, C. E. Inferring Signed Networks from Preschoolers' Observed Parallel and Social Play. *Soc. Netw.* **71** 80 (2022).
[2] Andres, G., Casiraghi, G., Vaccario, G Schweitzer, F. Reconstructing signed relations from interaction data. *Sci. Rep.* **13**, 20689 (2023).
[3] Tiago P. Peixoto. Reconstructing Networks with Unknown and Heterogeneous Errors, *Phys. Rev. X* **8**, 041011 (2018)