





















Figure 5: Comparison of the accuracy of link prediction with and without  $N_a$  in the training set. The bars show the AUC values of the link prediction problem in which no negative edges are known. The thick black lines represent the AUC values at the task in which some negative links are known. For the proximity-based prediction functions, the plot shows the AUC values of the inverted prediction functions, since they have AUC values of over 0.5 and are better suited to predict negative links. As expected, the best method when negative edges are known performs better than the best method when negative edges are not known. The observed difference, of about 0.05 AUC points, suggests that allowing negative edges gives an added value to a social network, but much less than expected, as that difference is smaller than the difference from one link prediction function to the next.

functions, showing that models such as preferential attachment, which predict a higher probability of edge attachment for nodes with high degree centrality, is valid independently of edge sign in networks where negative links are allowed. On the other hand, signed networks follow balance theory in that triangles in them tend to have an even number of negative edges, explaining why the proximity-based methods correlate negatively with the presence of negative edges.

## 6. CONCLUSION

We have shown that in the online social networks Slashdot and Epinions, the *foe* and *distrust* feature is used by users in a way that can be predicted to high accuracy from the *friend* and *trust* links. Thus, with regards maximizing the utility of news stream filtering and social recommendation, the negative link features of these two sites are redundant to a

large extent. However, it does not follow that these features are useless. Quite the contrary is true; the *foe* feature of Slashdot is used as a personal organization tool (remembering who is considered a *troll*), or simply to let another user know one's disapproval of them. In Epinions, the *distrust* feature is likewise central to the Epinions's Web of Trust.

As a solution to the generic learning problem of predicting one link type from another one, we showed that the usual link prediction methodology can be applied, but only with the caveat that individual link prediction function may have inverted performance, e.g., the cosine similarity measure in the example of disapproval links.

Finally, as an application of our methods to online social networks that do not allow *foe* or *distrust* links, we propose that a link prediction function learned using regression with Slashdot and Epinions data may be applied. The only way however to ascertain the accuracy of these predictions is to perform the evaluation described in this paper, which by nature of the problem is only possible when negative edges are known.

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