Predicting Hierarchical Structure in Small World Social Networks

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Abstract—**Typical analytical measures in graph theory like degree centrality, betweenness and closeness centralities are very common and have long history of their successful use. However, modeling of covert, terrorist or criminal networks through social graphs do not really provide the hierarchical structure of such networks because these networks are composed of leaders and followers. In this short paper we investigate small world networks by computing first the Bayes posteriori probability which is then used to calculate the entropy of the network. The computed probability and entropy distribution further utilized in predicting the command structure of the network.**

Keywords: Social Networks Analysis, Bayes Theorem, Entropy, Hierarchical Structure

1 Introduction

Drug dealers, terrorist and covert networks are typically, represented through social graphs. Since 9-11 terrorist attacks a great deal of research is taking place firstly to understand the dynamics of these terrorist networks (analysis) and secondly, developing methods to either destabilize or disintegrate these networks. Insight visualization of any social network typically focuses on the characteristics of the network structure. Social Network Analysis is a mathematical method for 'connecting the dots', SNA allows us to map and measure complex relationships/connections between human groups, animals, computers or other information/knowledge processing entities and organizations [1]. These relationships can reveal unknown information about these dots and the network itself. Jacob Moreno invented "Sociometry" which is the basis of SNA, utilized "sociograms" to discover leaders and map indirect connections in 1934 [2].

The two basic elements of SNA are connections and nodes. Connections are ties between individuals or groups and nodes are the individuals or groups involved in the network. There are different dynamics of social networking for example Kin-based (father, husband), Role-based (office), Interactions (chatting) and Affiliations (clubs etc). Analysts have applied SNA in many fields to reveal hidden informal links between nodes [3].

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For example in businesses SNA have been used to analyze email patterns to determine which employees are overloaded, similarly, law enforcement and national security organizations are using various method of SNA to identify important nodes and connections of terrorist organizations [4].

2 Method & Results

Given any network where the nodes/agents are individuals, groups, organizations etc., a number of network measures such as centrality or cut-points are used to locate critical/important nodes/agents. Typically, social network analysis try to identify the following characteristics:

- Important individual, event, place or group.
- Dependency of individual nodes.
- Leader-Follower identification.
- Bonding between nodes.
- Vulnerabilities identification.
- Key players in the network.
- Potential threat from the network.
- Efficiency of overall network

Networks visualization is semantically presented in the form of a graph in which the nodes represent entities and the arcs represent relationship among nodes. Classification of nodes and its distinctiveness is a challenging task, many traditional social network measures and the information processing network measures can help in revealing importance and vulnerabilities of the nodes/agents in the network [5, 6, 7, 8]. Application of existing tools on these complex socio-technical networks/systems is very demanding to winkle out the required information. Most of the measures and tools work best when the data is complete; i.e., when the information is inclusive about the interaction among the nodes. However, the difficulty is that covert and terrorist networks are typically distributed

across many boundaries for example from cities or countries and data about them is never complete-correct at a certain instant of time. Normally, a sampled snapshot data is available some of the links may be intentionally hidden. Also data is collected from multiple sources for example news (print/tv), open source Internet data, security agencies, etc., and at different time instants. In addition inclusive and correct information may be prohibitive because of secrecy. Obviously, there could be other difficulties but even these provide little guidance for what to expect when analyzing these complex socio-technical systems with the developed tools.

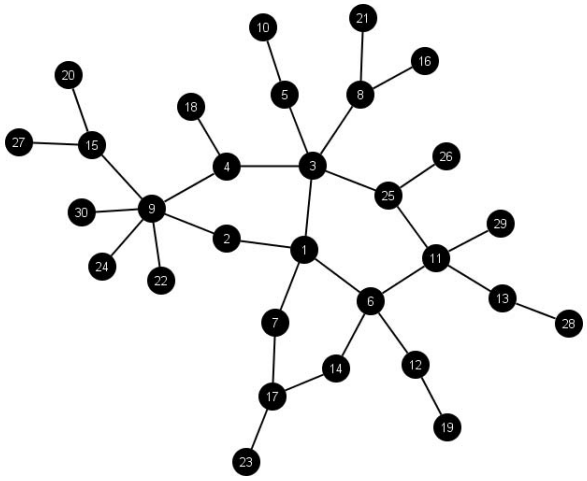

Figure 1: Small World Random Network Example

In this paper we are analyzing small world social networks systematically to compute Bayes posterior probability and then entropy of the network is determined by extracting each time a single node to reveal its position in the network structure. For the implementation of our proposed framework we have selected a 30 node small world network as shown in figure 1, after the computation of Bayes probability and entropy the network is re-structured based on the distribution of probability and entropy and it can be seen in figure 2 that it has a hierarchical structure approximately consistent with the importance of nodes.

3 Conclusion

The standard statistical solution for SNA has been matured for long time now and used in the studying social behavior however, elucidating the pattern of connections in social structure is very challenging and the conventional social network analysis may not be enough to reveal the structural pattern of nodes. The real world social networks including small world networks have varying complexity. The purpose of this paper is to investigate and locate the command structure in such networks. The

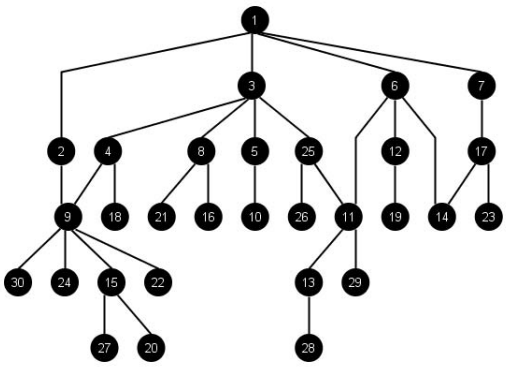

Figure 2: Hierarchical Structure of Nodes

idea of using such model is based on the underlying assumption philosophy of Bayesian Posterior Probability that uncertainty and degree of belief can be measured as probability. The initial investigation shows that it is possible to predict the command structure, however, these are preliminary results and one may not draw a solid conclusion from these investigation. In our future work we would like to extend this framework for more complexed and well known network structures available as open source for the consistency of our proposed hypotheses.

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