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Designing, Analyzing and Exploiting Stake-based Social Networks

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Abstract—**It is widely recognized that stakeholder information can provide important knowledge about stock investments, and an increasing number of countries require that such information is publicly available. In this paper, we present a novel way to exploit stakeholder information by using it to construct stake-based social networks, namely, StakeNet. We also provide a visualization tool that displays socio-centric and ego-centric views of the networks. In addition, we analyze stakeholders' static and dynamic behavior patterns in StakeNet, and demonstrate that most of StakeNet's properties are similar to those of a typical social network, except that the in-degree distribution does not follow a power law distribution. Finally, we demonstrate two applications of StakeNet by exploiting it to identify important companies and to group companies together. The experiments show that our results are highly consistent with the outcomes generated by human experts. Source code, dataset, and resources are available at http://www.csie.ntu.edu.tw/~d97944007/stakenet/**

Keywords-social network analysis; stakeholder analysis; stakeholder management

I. INTRODUCTION

The term "stakeholder" can be defined as "any group or individual who can affect or is affected by the achievement of the firm's objectives" [1]. In the information era, data about the stakeholders of publicly traded companies is being made available to investors in an increasing number of countries. Stakeholder data is important to stock investors because it provides information about individual companies and the relationships between companies. However, comprehending and utilizing stakeholder data is difficult because of the enormous volume available and the amount of detail involved. Furthermore, stakeholder data changes over time, and its dynamic nature makes the interpretation and usage of the data even more difficult. As a result, an intuitive and effective way to present, analyze and exploit stakeholder data is highly desirable.

In this paper, we propose a social network called StakeNet, which is constructed using stakeholder data. StakeNet is a directed, weighted, dynamic, and heterogeneous social network. We also investigate three issues for StakeNet. First, we provide a visualization tool that enables investors to view the relationships among companies and stakeholders in an in-depth and efficient manner. The tool can be utilized to examine the relationships of any given company as well as the overall market environment. Second, we represent Taiwan's stock market using StakeNet and perform on top of it both static and dynamic social network measures, such as the degree distribution, clustering coefficient, giant connected component analysis. Finally, we demonstrate the value of StakeNet by using it in two applications: rank important companies, and group companies into intra-related groups. The experiment results show that our system can achieve very high consistency comparing to the results generated by experts in investment companies.

II. STAKENET CONSTRUCTION AND APPLICATIONS

A. Constructing StakeNet

We define StakeNet as a graph $SN_{t\text{-}t'} = \{V, E\}$, where $V = \{v_1, v_2, \ldots, v_n\}$ is a vertex set, and $E = \{e_{ij} = \text{edge from } v_i \text{ to } v_j | 1 \le i, j \le n, i \ne j\}$ is an edge set. For each vertex v_k, type(v_k)$\in$ {*person, company*}; and for each edge e_{ij}, type(e_{ij}) $\in$ {*hold, manage, transfer*}. Weight(e_{ij}) equals the market value of the stocks (i.e., shares multiplied by prices) held or transferred by edge e_{ij} if type(e_{ij}) = *hold* or *transfer*. Note that the weight is zero if type(e_{ij}) = *manage*. Each type of edge can only occur between certain types of vertex, as shown in Table 1. For each specific time point, there is a corresponding StakeNet, since relationships can change over time.

We conducted a survey of the stakeholder information available in seven stock markets. The results show that Japan and Taiwan provide the most comprehensive publicly available stakeholder information. As a result, we took the Taiwan stock market as the data source and gathered stakeholder information from the official website of the Taiwan Stock Exchange[1]. The data covered the period 2002/10 to 2009/10, a total of 85 months. There were 2,026 publicly traded companies registered on the Taiwan stock market during that period.

TABLE I. EDGE AND VERTEX TYPES IN STAKENET.

Type of Edge e_{ij}	**Type of Vertex**	
	From v_i	***To*** v_j
Hold	Person or Company	Company
Manage	Person	Company
Transfer	Person	Person

B. Interrelation Visualization

We have developed a visualization tool that provides two views of a network: a socio-centric (global) view and an ego-centric (local) view. The socio-centric view displays the whole network, and the user can specify a minimum degree to control which vertices are displayed. In the ego-centric view, the user can specify a specific person / company and the level of interested neighbors, and the system will display a subgraph centered at the person /company for further investigation.

The socio-centric view (i.e., the global view of all nodes) in StakeNet constructed from 2008/11 to 2009/10 is shown in

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Figure 1. Due to space limitations, we only show vertices of degree ≥ 30. Total vertex number is 36,688, while total edge number is 43,538. The weights of the links represent the market value of the stocks held; zero-weighted links represent management relationships.

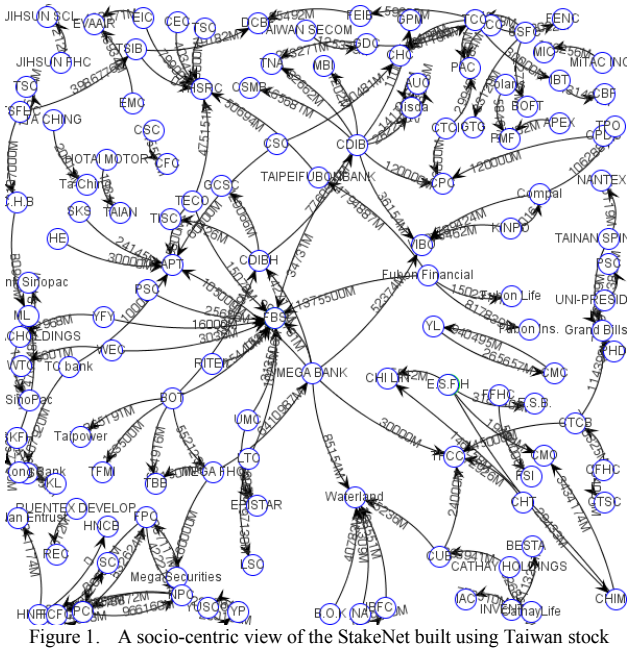

Figure 1. A socio-centric view of the StakeNet built using Taiwan stock market data from 2008/11 to 2009/10. Only vertices of degree ≥ 30 are shown.

C. Social Network Analysis via StakeNet

We apply social network analysis techniques to StakeNet. Static techniques, namely, the degree/weight distribution, clustering coefficient and average path length, are applied to gain an in-depth understanding of capital/resource allocation in the stock market. Meanwhile, dynamic techniques, such as changes in the number of links over time and the evolution of giant connected components over time, are measured to determine long-term trends in stock market behavior. We have two observations: (1) for company vertices the in-degree does not follow a power law distribution. We believe that this is because most stocks of publicly-traded companies in Taiwan are not held by a single shareholder and the average number of stakeholders in most companies is between 10 and 15. (2) The edge weight distribution is closer to a log-normal than a power law. This is because that our public stakeholders' data does not contain retail investors, which, if were included, should have been situated on the left-hand side of the distribution.

D. Corporate Ranking and Clustering

One potential usage for StakeNet is to rank or group companies based on their stakeholder information. Ranking reveals the importance or centrality of certain companies and clustering allows us to identify potential business groups. Investors can exploit such information to identify vertical / horizontal integration or even prevent possible insider trading. Here we apply centrality analysis (i.e. Weighted PageRank [2]) with random restart probability = 0.15, and find that most of the top ranked companies are banks, insurance companies, or industry leaders. We also exploit Edge Betweenness Clustering (EBC) [3] for community detection. The result is evaluated using Normalized Mutual Information (NMI) score [4]. We use the gold standard gathered from professional financial sources The Capital Group[2], with ground truth of 496 companies. We compare EBC with a greedy heuristic method, which simply groups companies having at least one identical stakeholder together. The difference between our methods with the baseline is that EBC utilizes the global topological information of StakeNet while the baseline results can be produced without using StakeNet. The result shows that EBC (0.97 in NMI) outperforms the baseline methods (0.70 in NMI) significantly. The results show that the StakeNet does provide useful information for corporation grouping.

III. Conclusion

This paper proposes a novel type of social networks: StakeNet, constructed from stakeholder information. We provide socio-centric and ego-centric visualization tools for the networks. Also, we find the degree distributions of StakeNet generally follow the power law distribution, except for the in-degree distribution of company vertices; and the market value of the stocks held by people follows a log-normal rather than a power law distribution. Finally, we propose using StakeNet to rank and group corporations and conduct experiments to show the usefulness of our proposal. We believe that StakeNet can provide in-depth and systematic insights for investors.

One possible application of StakeNet is link prediction. Since StakeNet is a dynamic social network, using old networks to predict new coming links might be plausible. Another possible research avenue is the use of StakeNet for anomaly detection to identify companies or individuals engaged in abnormal behavior, such as insider trading.

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