Trust Network and Trust Community Clustering based on Shortest Path Analysis for E-commerce

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Abstract

Trust in e-commerce has become one of the most important issues in online applications. Constantly, a user will only search for the most credible of goods and service providers and then take on their transactions. How to confirm which service providers are the most trusted for a user has become the most critical problems. This paper presents a trust network and trust community clustering for the analysis of the users most trusted relationship. It uses the nodes to represent the various subjects involved in the trust and use the connection links to denote relationships. The weight of the links indicates the strength of the relationships. First, it construct a trust network diagram which has the weight value of links, and then to analyze the clustering properties of the relationship according to the weights and the path length. At last, it classifies the most trusted subjects to the same cluster for a user. Direct trust information degree and global trust information degree are used to evaluate trust relations among subjects and it gives an improved shortest path algorithm to construct trust network. A clustering algorithm based on coefficient and path length is presented for E-commerce trust network community. Experiments show that the method of building trust through the network model can well describe the main indirect E-commerce trust and the algorithm has obvious advantages in accuracy and time cost.

Keywords: *E-commerce; trust information degree; shortest path algorithm; trust community clustering*

1. Introduction

We can use the complex, interactive network node and network connections to represent the interests of the subjects and the interactions or relationship between them in E-commerce trust [1]. Many researchers have studied the subject of the network model of trust. This can help them to understand the subject of credibility and trust between subjects. The results show that the trust relationship between subjects to another can be regulated by trust network model and support the function of other's trust or credibility [2, 3, 4]. Trust network in e-commerce is a one of social network. We can use the tool of social network analysis to study the theory and methods. In the past, people have been extensively studied on social networks. Many scientists have studied the structure and properties of the large and complex network [5, 6, 7]. Such as small-world networks, collaboration networks, multi-scale networks and community networks in their attributes analysis of the structure and the topology [8, 9, 10]. These networks and have very similar characteristics and properties with E-commerce trust networks.

Most studies in the past have focused on the study of a single subject, or trust in the credibility of the establishment of the issue. There is less in the network relationships of trust issues between subjects in E-commerce applications of real confidence. For example, in the trust evaluation model of subject, the majority of researches focus on the trust and credibility of the subject, and by the properties and characteristics of the individual to establish trust and credibility for impact on the surrounding association to determine the subject. This kind of trust and credibility is unchanged in the network. For any subject in the network, its trust degree is the same. However, it is difficult to trust a credibility which establish by unilateral confidence due to the uncertainty of the sources of information and breadth of the subject in e-commerce environment. Trust relationship between subjects is different in reality trust network. That is the trust degree is different that a subject to another subject compare to the subject to others. In addition, a direct trust degree between a subject and another does not mean that the degree of global one between them. One could decide whether to buy a product by some passed the evaluation of other users though he has not interact with the merchant when he brows products in E-commerce. These users may have he same characteristics or properties with the user. The user may trust these users which are in the trust network and then trust their review and purchase the goods. Therefore, a trust relationship of the trust and credibility in e-commerce environment needs an evaluation model which is established on self-trust relationship.

It establishes a trust network model of E-commerce by social network analysis. A direct trust information degree and a global trust information degree are used to build trust relationship among the subjects in trust network. An improved shortest path algorithm is used to build trust network model. It implements trust community clustering analysis through the clustering coefficient and global trust information degree and presents an improved clustering analysis algorithm for trust community.

2. Social Networks and Trust Network of E-commerce

2.1. Social Network Analysis

The research of relationship of social network can be traced back to the 1960s in the field of sociology. Milgram found the characteristics of small world in social network analysis [11]. Since then, many researchers made an extensive research on social network structure and their characteristics. With the development of computer science and network technology, it is growing in popularity in computer science. In the related research in the social network, the graph model is a very important modeling tool. It has been abstracted an individual into a node and the relation between the individuals into the link. And then, a graph structure is built. Through the study of this particular graph can analysis and mining the internal pattern and information that be implied. Graph model can be applied in sociology, human behavior, transmission of disease and information and communication aspects of the Internet and other online communities. Recently, some researches of data mining and structure mining technical have proved that these networks have the small world properties and characteristics. In order to improve the efficiency and scalability of SA-Cluster, Zhou proposes an efficient algorithm Inc-Cluster to incrementally update the random walk distances given the edge weight increments [12]. And Wu proposes a framework of an exact solution and an approximate solution for computing ranking on a subgraph. He proved that the IdealRank scores for pages in the subgraph converge and analyzed the distance between IdealRank scores and ApproxRank scores of the subgraph [13].

2.2. Trust Network of E-commerce

In e-commerce environment, Business subjects, including consumer and business, their trust and credibility has become an important issue which affects the development of E-commerce. There are trust relationships exists between consumers to consumers, businesses to businesses, and consumers to businesses. These relationships directly affect a user whether to trust quality review of another user of a certain goods, business or service. And it directly impact on the user's determination for the quality of business, goods or services. And further affect the user's choice of goods and services.

We can evaluate the trust relationship of subject through social network analysis. Golbeck proposed a trust inference mechanism for trust relation establishment between a source participant and the target one based on averaging trust values along the social trust paths [14]. G. Liu put forward a framework of trust propagation to study the complex social network by the path selection problem and a new concept Quality of Trust is used to guarantee a certain level of trust worthiness in trust propagation along a social trust path [15]. R. James examined the role of trust from various aspects within telemedicine, with particular emphasis on the role that trust plays in the adoption and adaptation of a telemedicine system [16].

3. Construction of Trust Networks

3.1. Trust Information Degree

In a trust network, the level of trust between one node to another can be expressed by metric function of trust. Trust degree is the theoretical basis for evaluation model of a trust network.

A well-designed trust degree plays a vital role in the accuracy of assessment for trust relationships in network. In this paper, we introduce mutual information function as a measure of confidence in the assessment of the trust network model. Mutual information is used to indicate certain information that sent or received some information and brought out some variable information in information theory. If there are two nodes which have a trust relationship in the trust network, you can get some information about another node when the information of the one node is received. This information can be measured by mutual information. Therefore, it can determined trust relationship through mutual information between two nodes. And it can measure the size of the trust.

Definition 1(trust information degree): For a rust network space, there are $G=(V,S)$.where V is the set of nodes in all the space. S is the set of links in all the space. Let v_i and v_j are two different nodes on the space. The trust information degree is defined as $Bel(v_i,v_j)$.

$$Bel(v_i,v_j)=\sum\sum p(v_i,v_j)\cdot\log\frac{p(v_i,v_j)}{p(v_i)\cdot p(v_j)} \tag{1}$$

From the trust information degree, we can find the distance between the joint probability density function of v_i and v_j on domain U , that is $p(v_i,v_j)$,and $p(v_i)\cdot p(v_j)$, reflects the size of mutual information of the variables. When the node

v_i and v_j independent each other, there is $p(v_i,v_j) = p(v_i) \cdot p(v_j)$.this represents that the distance between $p(v_i,v_j)$ and $p(v_i) \cdot p(v_j)$ is zero. And then the mutual trust information degree is zero ; when there is trust relationship between v_i and v_j ,that is when $p(v_i,v_j) \neq p(v_i) \cdot p(v_j)$,and then the distance between $p(v_i,v_j)$ and $p(v_i) \cdot p(v_j)$ is not zero. Furthermore, the more the distance, the less the mutual information. And the trust information degree is larger between v_i and v_j .In this case, the trust relationship of v_i and v_j is more obvious.

3.2. Direct Trust Information Degree

Definition 2(direct trust information degree): In a trust network, if there are history relationships between two nodes v_i and v_j , and the two nodes conditional independent each other, then the trust information degree can be obtained by equation (1). This kind of trust degree is call directed trust information degree, label as $Bel_d(v_i,v_j)$.

Direct trust information degree is assessed by computing directly interact recorded history of the nodes and the others. We use the total number of historical interaction, the number of successful interaction, the number of failures and the probability relationship between their mutual interactions as the basis for direct credibility.

Assume that the $A_{i,j}$ is the total number of the direct interaction at a time interval for node v_i and v_j . The $T_{i,j}$ represents the number of successes and $F_{i,j}$ the number of failures for node v_i and v_j .we use $A_{i,j}, T_{i,j}$ and $F_{i,j}$ to construct direct trust information degree for node v_i to v_j .the degree is represents by $Bel_d(v_i,v_j)$ and the $Bel_d(v_i,v_j)$ is the direct trust information degree function of node v_i to v_j .

There is a direct trust information degree between any two nodes in a trust network. The direct trust information degree between them is zero when the direct interaction history is empty between the two nodes. The calculation algorithm is as follows.

Algorithm 1: Calculation the direct trust information degree of any two nodes

Step 1: Select any one node v_i , count the interaction history of it to another node v_j and calculate function $A_{i,j}, T_{i,j}$ and $F_{i,j}$.

Step 2: If $A_{i,j} \neq 0$, then calculate the trust information degree through equation (1).that is: $Bel(v_i,v_j) = \sum\sum p(v_i,v_j) \cdot \log \frac{p(v_i,v_j)}{p(v_i) \cdot p(v_j)}$

If $A_{i,j} = 0$, then let $Bel_d(v_i,v_j) = 0$.

Step 3: Repeat with the next node and until have searched all network nodes through space.

3.3. Globe Trust Information Degree

Direct trust information degree can be calculated by direct interaction history between two nodes. But if the history of their interaction is none, then the direct trust value is zero. However, this does not mean that these two nodes trust relationship does not exist. This trust value can be passed through other nodes. This kind of trust which is obtained by pass through others is global trust information degree. Global trust information degree is to consider the overall degree state of trust. Trust between two nodes is inevitable affected by the direct and indirect information that of other nodes in network. Thus this effect will affect the relationship of trust between the two nodes. In addition, if there is no direct connection links between two nodes, the trust information degree between them will be calculated out through trust value of the intermediate nodes in the network.

Definition 3(globe trust information degree): the trust relationship between node v_i and v_j can be assessed through global relationship in the whole network. This trust degree is defined as globe information degree of node v_i and v_j and be represented as $Bel_a(v_i, v_j)$.

In this paper, an improved shortest path algorithm is adopted to calculate the globe trust information degree. Shortest path algorithm is a typical graph search algorithm that widely used in graph model. The algorithm assesses the optimal path between nodes by detecting edges weight connected nodes. The theory and methods of graph model can be used to search the optimal path in finding trust relationship network structure. The best path in here is no longer the shortest path, but is the optimal path for trust. It includes multiple nodes in this trust path. These nodes can be look as the best relationship of trust from the source node to destination node. By analyzing the global trust information degree of these nodes to destination node, the trust relationship that these nodes to destination node can be determined. These trust information status are the most important reference for source nodes. The source user may most trust the credit evaluation that those user are on the trusted path who appraise some product or business in E-commerce. Thus it will affect the source user to purchase target goods or services. Apparently, the source user has no direct interaction with target goods or business. This mechanism solves the problems of having no way to trust and to determine for user when he wants to purchase some goods facing the variety of user evaluation. The method provides a right feasible solution for the user to choose a valuable, trusted and objective evaluation.

The existing search algorithm of research networks for shortest path most focused on the analysis links of building structure. And less for the relationship between the nodes of the search problem. Especially at the time of the absence of a direct connection between two or more entities to build a network. In addition, the found path should be reflecting the fact that the most closely linked between nodes in order to provide the most important fact. The typical relationship searching algorithm is breadth-first search methods in the existing analysis. However, the algorithm can not find the closest relationship between nodes. It is often limited to direct search and difficult to achieve the global search there is no direct contact or indirect relationship. To this end, we improve the basic BFS algorithm in the paper.

Algorithm 2: An improved BFS algorithm

Input: The source node s and terminal trust node t ,the direct trust information degree $Bel_d(v_i, v_j)$ of Between any two nodes in the space.

Output: The globe trust information degree of source trust node s to terminal trust node t , $Bel_a(s,t)$.

Step 1: Let T is a set of a tree and $T = \{s\}$;

Step 2: Select a node v_i and let $v_i \neq s$,calculate the direct trust degree $Bel_d(s, v_i)$ by algorithm 1.

Step 3: If the value $Bel_d(s, v_i)$ Less than a threshold value ε , that is $Bel_d(s, v_i) < \varepsilon$,then Discard the node and go to Step 2.If there is $Bel_d(s, v_i) \geq \varepsilon$,then to the next step.

Step 4: If the node is in set T then go to Step 2. If the node is not in set T Then add the node in the tree T and set the node s as the parent node of v_i ,that is let $T = T \cup \{v_i\}$ and $Pa_{v_i} = s$.

Step 5: for each node v_i which is on the path from s to t :

(1).If the value of information degree $s \to v_i$ is the Maximum, then set the path into s .

(2). If the node v_i is an Intermediate node on the path and it is on the path of $s \to t$,then delete the node v_i and link its parent node and subnode.

(3). If the path $v_i \to t$ is on the path of $s \to t$, then set the path into t until there is no node on the path $s \to v_i$ which is on the path $v_i \to t$. If the resulting tree nodes which have a path set are a subset of another set of nodes of a path, then delete the path. And then set the leaf node into one node.

(4).calculate the trust information degree value of the path.

$$Bel_a(s,t) = Bel_d(s, v_1) \cdot Bel_d(s, v_2), ..., Bel_d(v_i, t) \qquad (2)$$

4. Clustering Analysis of Trust Community

The purpose of the trust community clustering in the trust network is divided into a high degree of mutual trust community from the trust subjects. In these communities, the main body of each trust subjects has a high degree of global trust information. They can share evaluation of the goods or services among the subject in a same community and share the experience degree of E-commerce. This help people to remove interfering factors in e-commerce environment and extract the most valuable information.

4.1. Clustering Coefficient

Watts and Strogatz used clustering coefficient to describe the network node connection degree in small-world network analysis. In fact that the clustering coefficient can also be used in terms of small-world network or multi-scale network. We can use it to describe the characteristics of network structure in other complex network analysis. Clustering coefficient represents the closeness of a node with other nodes on behalf of the network. It denotes the degree of trust in E-commerce network between the business subjects. For node v with a k degree (k denotes there are k connected edges), its clustering coefficient can be defined as:

Clustering coefficient C: it is a measurement parameters of the closely degree of neighbor nodes. C_v denotes the ratio of actual number of edges of subgraph to that with the largest number of edges:

$$C_v = \frac{2t_v}{k_v(k_v - 1)} \tag{3}$$

k_v is the number of neighbor nodes. Let C denotes the mathematical expectation of C_v of all nodes, and then the expectation is the clustering coefficient:

$$C = \frac{\sum_{n=1}^{\infty} C_v}{n} \tag{4}$$

Clustering coefficient describes tightness hold together of the nodes on the network. It is the local features of a network. Among them, n denote the number of edge that the node v connected neighbor nodes.

4.2. Clustering Algorithm for Trust Community

In order to establish a high clustering and high information degree of trust network clustering, we use the global trust information degree as the evaluation factor, which is distance between two nodes in the network. One difference with the distance function in the trust network is that the greater the degree of information, the smaller the distance that the path is. Conversely, the smaller the degree of information, the greater the distance. Clustering of trust network is to achieve some nodes and links, which mutual trust information degree have reached a threshold, into a same community. The clustering will be has a high clustering, high-trust properties.

Definition 4: For a trust network, a sub-graph is a clustering of subjects of E-commerce, which is obtained by deleting m arcs from the regular network so that maximizing $f = aBel_a + bC|_m$, when a regular network $G = (V, S)$ with k degree is given. In which V is subjects nodes set and S is arcs or links set. In conditional parameter $f = aBel_a + bC|_m$, a and b are constants, m is integer, Bel_a and C is characteristic path length and clustering coefficient respectively.

Solving the optimal connectivity problems of the nodes in this network is a NP problem. We propose an algorithm for the optimization as follows.

Specific clustering algorithm for trusted community network is as follows:

Algorithm 3: Trust Community clustering

Step 1. Repeat cut an arc, which could maximize f, until m arcs are moved.

Step 2. Join an arc that could maximize f and make a judgment. If the joined arc is the same as the cut one then the algorithm will end.

Step 3.cuting an arc, which can maximize f and then jump to Step 2.

The parameters Bel_a and C that satisfy the maximal $f_{\max}$ are the clustering about the nodes, in which the clustering group can be expressed as follow:

$$V' = \{v_i \mid v_i \in V \wedge Bel_a \geq \mu\} \tag{5}$$

5. Experiment and Analysis

P. Massa [17] used a large online community Epinions data sets to evaluate the trust relationship. We also use the data set to analysis the performance of clustering trust community. Epinions data set is a who-trust-whom online social network of a general consumer review site Epinions.com. Members of the site can decide whether to trust each other. All the trust relationships interact and form the Web of Trust which is then combined with review ratings to determine which reviews are shown to the user [18]. The data set consists of two parts, the rating_data sets and trust_data sets. Rating_data sets include three items, the user_id, item_id, rating_value, and comprising about 49,290 user's nodes, rating of 139,738 items. Trust_data sets consist of source_user_id, target_user_id, trust_statement_value, and comprising 49,290 user nodes trust status. We let the rating data set as training data and use algorithms 1 to 3 to build trust communities. The trust_data sets trust looked as a test set to assess the accuracy of the results.

In order to test our algorithms we use other two different algorithms to compare them. The first algorithm is a standard Collaborating Filtering one and the second is Mole Trust [17].

The validity of community clustering of trust network can be evaluated by the accuracy and time efficiency. When the trust community cluster that node included is in the consistency with higher confidence of trust_data sets, it indicating that the nodes in the community cluster have close relationship of trust with other nodes in the same community and it shows the trust community clustering is correct. When there is low confidence in the consistency of trust_data sets, it shows the trust community clustering is incorrect. In this case, nodes in the same trust community cluster exist not a high trust relationship. The Accuracy is defined as:

$$Accuracy = \frac{N_c}{N_c + N_i} \tag{6}$$

Where N_c is the number of correct nodes and N_i the incorrect. The results show in graph 1 to 3. The horizontal lines represent the number of nodes in the test samples set;

the vertical line represents the accuracy of clustering community. Comparison of three methods shown in Figure 1.

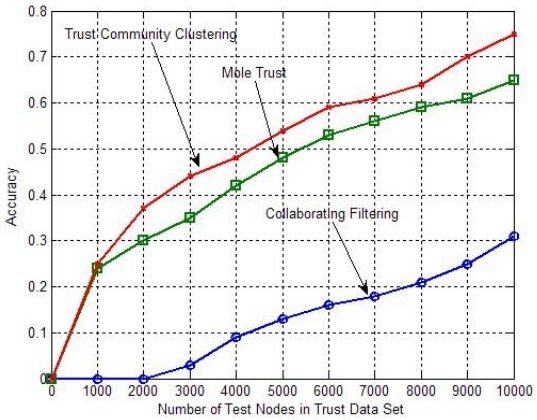

Figure 1. The Trend Line of Accuracy for the Three Algorithms

In the trust before the 10000 test samples, the standard Collaborating Filtering relatively has a low accuracy of the algorithm. For the other two algorithms they have a higher accuracy of the results, in which the Mole Trust reached 0.6 at 9000 samples and community clustering can achieve 0.7.

The Mean Absolute Error is also used to analysis accuracy also. The horizontal line indicates the number of sample nodes; vertical line represents the MAE, a comparison of the three methods shown in Figure 2.

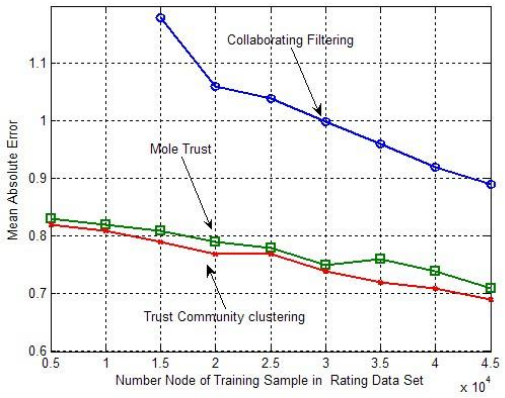

Figure 2. The MAE of the Three Algorithms under Different Number of Training Nodes

From above we can see that there is a certain influence on the results from the number of training samples. When the training samples are low, the errors are higher. When the number of samples for more than 45,000, the error is significantly reduced.

By selecting the different thresholds to test the convergence of the algorithm. Take 0.6, 0.8 and 0.10, respectively, which to analyze the algorithm's execution time. The results shown in Figure 3.

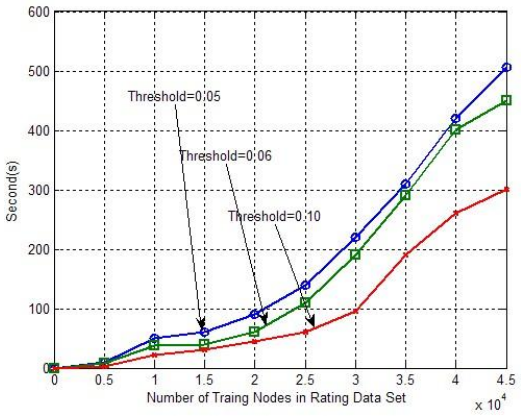

Figure. 3. The Seconds of Convergence under Different Threshold

6. Conclusion

A trust network model in E-commerce by social network analysis is established in this paper. This model combines direct trust information degree and global trust information degree. It has an advantage of building a trust relationship network between the subjects. It proposes an improved shortest path algorithm to build trust network model. It proposed the concept of trust community networks and through community clustering analysis to construct trust relationship. It also gives the algorithms for the global trust information degree and trust community clustering in E-commerce. The experiments show that the method of building trust network model can well describe the main indirect trust in E-commerce and the algorithms has obvious advantages in accuracy and in time cost.

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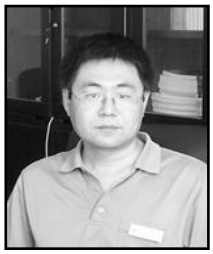

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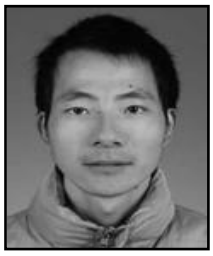

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