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PATH ALGEBRA FOR TOPIC TRUST COMPUTATION BASED ON REFERENCES OF USERS IN SOCIAL NETWORK

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Abstract

Topic trust in social networks is defined based on combination of interaction experience and user interests. While interests are introduced to classifying users into topics, interaction among users is modeled as a directed graph with weights being a number of connections between nodes. However, such a computation is mainly based on direct interaction being available among users. When direct connections among partners is unavailable, the above model of computation is not applicable. In this paper, we first present a reference topic trust model based on path algebra for topic trust in the context of lacking connection between users. Then we describe an algorithm for estimating such topic trust values.

1 Introduction

In social networks, users utilize their own tags to annotate and organize items for searching or sharing viewpoint or opinions. Such tags are a kind of meta-data composed of keywords or terms to introduce bookmarks, article titles, comments of items or digital images etc. They have contributed to discovering

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user interests for various real world applications such as recommender systems, searching engine, predicting customer opinions ([1] [2] [4] [11] [16]). Trust has become crucial for partners to share or post their messages through interaction and has attracted increasing research interests in computer science. There are various models of computational trust proposed in literature ([5] [6] [7] [10] [13]). These approaches are mainly based on trust via interaction among partners. Some researches [12] extends computational trust by combining experience trust via interaction and user interests via tags on items such as books, articles, images etc.

In many social networks such as Facebook, Twitter etc., such trust values have been not provided by users. And then the proposed combination computing model [12] is not applicable. Our novel model of trust computing [3] has been proposed by integration of interaction and user interests. Interaction among users in social network are modeled as a directed graph, in which the weight of an edge is a number of connections between nodes. Tags will be used to show user interests. And in turn, interests are introduced to classifying users in topics. By means of weights of connection among users and the classification with topics, we can compute values of topic trust of a user on another one. However, such a computation is based on assumption that all agents have direct connections among them. And then, when there is no direct interaction among two users, such computation is unattainable.

In this paper, we will present a computation model of reference topic trust, which makes use of path algebra for estimating trust values via propagation. The proposed model is to deal with the case when there is no direct interaction among users. The remainder of this paper is structured as follows. Section 2 briefly presents experience trust topic. Section 3 is devoted to problem statement and presents path algebra for extending trust for reference trust computing. Section 4 is conclusions.

2 Experience based Topic Trust

This section briefly presents the model of integration trust computation of experience via interaction and user interests via topics (Refer to [3] for more detail). For convenience in reading, we represent two algorithms to estimate experience trust and experience topic trust values.

2.1 Interest and Expert

Suppose that n_t^i is the number of tags a user u_i has dispatched in some topic t. Then the interest level of u_i on topic t is defined by the following formula

$$interest_{topic}(i,t) = \frac{1}{2}\left(\frac{n_t^i}{\sum_{l\in\mathcal{T}} n_l^i} + \frac{n_t^i}{\sum_{u_k\in\mathcal{U}} n_t^k}\right) \tag{1}$$

The expert level of a user u_i on a topic t is defined to be the interest level a user has via posting tags

$$expert_{topic}(i,t) = interest_{topic}(i,t) \tag{2}$$

2.2 Experience based Topic Trust

Experience trust of user u_i on user u_j, denoted $trust^{exp}(i,j)$, is defined by the formula

$$trust^{exp}(i,j) = \frac{\|I_{ij}\|}{\sum_{k=1}^{n_i}\|I_{ik}\|} \tag{3}$$

where n_i is the number of users, with whom u_i has interacted and $\|I_{ik}\|$ is the number of connections u_i has performed with each u_k.

Definition 1. *Suppose that $trust^{exp}(i,j)$ is the experience trust of u_i on u_j and $expert(j,t)$ is the expert of u_j of topic t. The trust of u_i on u_j of topic t is defined by the following formula:*

$$trust_{topic}^{exp}(i,j,t) = trust^{exp}(i,j) \times expert(j,t) \tag{4}$$

Steps for estimating experience trust of truster u_i on u_j via interaction is described in **Algorithm 1**.

Steps for estimating the value of topic trust of truster u_i on u_j of topic t *experience topic trust* in the social network is described in **Algorithm 2**.

3 Trust Computation through Propagation based on Path Algebra

3.1 Problem Statement

Given two users u_i and u_j. The problem is how to compute a topic trust of truster u_i on trustee u_j of topic t. There are three cases:

Algorithm 1 Experience Trust of u_i on u_j via connections

Input: The set of users $\mathcal{U} = \{u_1, u_2, ..., u_m\}$ with connections
Output: The experience trust of u_i on u_j, $calculateTrust^{exp}(i, j)$.

for all $u_i \in \mathcal{U}$ **do**
  for all $u_k \in \mathcal{U}$ **do**
    $n_{ik} \leftarrow numberOfConnection(i, k)$ //Number of connections u_i has on u_k
    if $n_{ik} > 0$ **then**
      $n_{ik} \leftarrow n_{ik} + 1$
    end if
  end for
  $trust^{exp}(i, j) \leftarrow \frac{n_{ij}}{\sum_{k=1}^{n_i} n_{ik}}$
end for
return $trust^{exp}(i, j)$

Algorithm 2 Topic Trust of u_i on u_j of topic t

Input: The set of topics $\mathcal{T} = \{t_1, t_2, ..., t_n\}$ and the set of users $\mathcal{U} = \{u_1, u_2, ..., u_m\}$ with tags
Output: The trust of u_i on u_j of topic t, $calculateTrust^{exp}_{topic}(i, j, t)$.

for all t in $\mathcal{T}$ **do**
  for all $u_i, u_j \in \mathcal{U}$ **do**
    $n_i^t \leftarrow numberOfTags(i, t)$ //Number of tags u_i post on topic t
    $trust^{exp}(i, j) \leftarrow calculateTrust^{exp}(i, j)$ //Algorithm 1
  end for
  $expert(i, t) \leftarrow \frac{1}{2}\left(\frac{n_t^i}{\sum_{l \in \mathcal{T}} n_l^i} + \frac{n_t^i}{\sum_{u_k \in \mathcal{U}} n_t^k}\right)$
end for
$trust^{exp}_{topic}(i, j, t) \leftarrow trust^{exp}(i, j) \times expert(j, t)$
return $trust^{exp}_{topic}(i, j, t)$

(i) There is some direct interaction between u_i and u_j, the trust value is then computed based on *experience topic trust* described in **Algorithm 2**.

(ii) There is no any direct interaction between truster u_i and trustee u_j. Assume that there exists a sequence of users u_k $(k = 1, \ldots, n)$ such that they have interaction in couple with each others. It means that u_i

connects with u_1,u_1 connects with $u_2, \ldots, u_n$ interact with u_j. Then trust estimation is defined via the path from truster u_i to trustee u_j.

(iii) In the case where there exists no any such path is out of concern of this paper.

The purpose of this paper is to deal with situation (ii). And then the trust estimation needs to be based on middle trustees that has direct interaction with each others. The trust value is then called topic trust based on reference or briefly *reference topic trust* and denoted $trust^{ref}_{topic}(i, j, t)$. This section is devoted to presenting an approach based on path algebra for estimating such trust values.

3.2 Reference Topic Trust Computation

3.2.1 Path Algebra for Trust Computation Propagation

Given two nodes u_i on u_j, which has not direct connection with each other. Suppose that there is a path connecting u_i and u_j via nodes u_k $(k = 1, \ldots, n)$. We can estimate trust value, called *reference topic trust*, $trust^{ref}_{topic}(i, j)$ by making use of of path algebra to merge experience topic trust values along a path. Path algebra provides a means to estimate trust via concatenation and aggregation. It is constructed based on two operators $\oplus$ and $\otimes$, which is reformulated in terms of the context of our paper (Refer to [8] [9] for more detail).

Definition 2. *Given a directed graph $G = (V, E)$. Each edge $e_{ij} \in E$ connecting the source i and the destination j is associated with a label $l(e_{ij})$, which may be a real number or a vector.*

For example, in our computational trust model, the label is a vector of experience topic trust values $< trust^{exp}_{topic}(i, j, t_1), \ldots, trust^{exp}_{topic}(i, j, t_n) >$, where $t_1 \ldots, t_n$ are topics. For simplicity in presentation, we are concerned with some topic and denote the label to be $trust^{exp}_{topic}(i, j, t)$ rather than a vector.

Definition 3. *A path from node i to node j, denoted $p(i, j)$, is the concatenation of an ordered set of labeled edges $e_{(k,k+1)}$, where $k = i, \ldots, j-1$. The label associated with the path, denoted $l(p(i, j))$, is a function of the labels associated with the edges in the path through the concatenation operator $\otimes$ of labels.*

For example, in our computational trust model, the label of a path from u_i to u_j is computed to be $\otimes$ of topic trust $\otimes_{k=i}^{j-1} trust^{exp}_{topic}(k, k + 1, t)$.

Definition 4. *Given two nodes u_i, u_j in the directed graph $G = (V, E)$. Denote $\Phi(i, j)$ to be the set of paths $p(i, j)$ connected u_i and u_j. The label for the set $\Phi(i, j)$ is defined as a function of labels of paths $p(i, j)$ by using an aggregation operator $\oplus$.*

The following properties are useful for computing trust in various cases.

Proposition 1. *The operators concatenation and aggregation has the following properties:*

(i) Operator $\otimes$ is associative and commutative;

(ii) Operator $\oplus$ is associative and commutative.

The property (i) confirms that the trust estimation of a sequence of nodes depends not on the order of computation. The trust estimation via a middle user is called *reference topic trust*, denoted $trust^{ref}_{topic}(i, j, t)$, which is defined in the next definition. The property (ii) permits us to estimate trust in paths in any order. For example, there are q various paths connecting i, j, we can compute $\oplus$ in order of any couple to get the final value.

3.2.2 Reference Topic Trust

In this paper, we make use of the usual multiplication $\times$ for concatenation $\otimes$ and the maximum max for aggregation $\oplus$. A discussion of advantage and disadvantage of operators is out of our paper (Refer to [8] for more detail). The following definition on reference topic trust provides a formula for estimating trust values.

Definition 5. *Suppose that $\Phi(i, j)$ to be the set of paths $p(i, j)$ from u_i to u_j. Then the reference trust of u_i on u_j of t is defined by the following formula:*

$$trust^{ref}_{topic}(i, j, t) = \max_{p(i,j)\in\Phi(i,j)} trust^{p(i,j)}_{topic}(i, j, t) \tag{5}$$

in which $trust^{p(i,j)}_{topic}(i, j, t) = \prod_{k,l} trust^{exp}_{topic}(k, l, t)$ is the topic trust of i on j through the path $p(i, j)$.

The steps of computing reference topic trust of u_i on u_j by means of its neighbors with concatenation and aggregation operators are described in **Algorithm 3**.

4 Conclusions

In this paper, we have introduced an approach of reference trust computation to deal with the situation lacking of direct interaction among users. We make use of path algebra for propagation of experience topic trust values when there is yet direct interaction among users. There are some open problems in our work. The first one is how to reduce computation complexity due to propagation. Second, if reference topic trust estimation depends on selecting the various

Algorithm 3 Reference Trust of u_i on u_j of topic t

Input: The set of topics $\mathcal{T} = \{t_1, t_2, ..., t_n\}$ and the set of users $\mathcal{U} = \{u_1, u_2, ..., u_m\}$

Output: the trust of u_i on u_j of topic t, $calculateTrust^{ref}_{topic}(i, j, t)$.

1: $\Phi(i, j) \leftarrow constructPathSet(i, j)$ //the set of all paths from u_i to u_j
2: **for all** t in $\mathcal{T}$ **do**
3: **for all** $p(i, j) \in \Phi(i, j)$ **do**
4: $trust^{p(i,j)}_{topic}(i, j, t) \leftarrow \prod_{k,l} trust^{exp}_{topic}(k, l, t)$ //Algorithm 2
5: $trust^{ref}_{topic}(i, j, t) \leftarrow \max_{p(i,j)\in\Phi(i,j)} trust^{p(i,j)}_{topic}(i, j, t)$
6: **end for**
7: **end for**
8: **return** $trust^{ref}_{topic}(i, j, t)$

types of operators. The issues need to be investigated furthermore. We are currently performing experimental evaluation and comparing with other models on computing trust in social network. The research results will be presented in our future work.

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