A Trust Propagation Model for New-Coming in Multi-agent System

Manh Hung Nguyen[1,2](✉) and Dinh Que Tran[1]

[1] Posts and Telecommunication Institute of Technology (PTIT), Hanoi, Vietnam
[2] IRD, UMI 209 UMMISCO, IFI/MSI, Vietnam National University of Hanoi, Hanoi, Vietnam
{nmhufng,tdque}@yahoo.com

Abstract. In order to cooperate in the open distributed environment, truster agents need to be aware trustworthiness of trustee agents for selecting suitable interaction partners. Most of the current computational trust models make use of the truster itself experience or reputation from community on trustees to compute the trust values. However, in some circumstances, a truster agent may have no experience with a new trustee or may not obtain the information about the reputation of the new trustee agent. And then the truster agent could not utilize the traditional mechanisms based on experience or reputation to infer some trust value for the new trustee. In this paper, we introduce a novel mechanism for estimating trustworthiness in such a situation. Our proposed mechanism is based on the similarity in profiles of the new trustee and ones of well known agents. A weighted combination model is used for integrating experience trust, reputation and similar trust.

Keywords: Trust · Reputation · Trust propagation · Trust similarity · Multi-agents system

1 Introduction

Trust is a directional relationship between two parties in which one side called truster assesses trustworthiness on another side called trustee. This concept has been investigated and utilized in various application areas. Josang et al. [9] consider trust as the extent to which a given party is willing to depend on something or somebody in a given situation with a feeling of relative security, even though negative consequences are possible.

From the computational point of view, Grandison and Sloman [3] define trust as a quantified belief by a truster with respect to the competence, honesty, security and dependability of a trustee within a specified context. This understanding of trust has been accepted and applied to constructing open distributed multiagent systems. The model given by Nefti et al. [12] considers some kind of information on a merchant website that is shown to increase customer trust. Yu and Singh [22–24] propose a model to store values of the quality of

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direct interactions among agents and only consider the most recent experiences with each partner for the calculations. Sen and Sajja's [19] reputation model considers both types of direct experiences: direct interaction and observed interaction. While the main idea behind the reputation model presented by Carter et al. [2] is that the reputation of an agent is based on the degree of fulfillment of roles ascribed to it by the society. Sabater and Sierra [17,18] introduced ReGreT - a modular trust and reputation system oriented to complex small/mid-size e-commerce environments, where social relations among individuals play an important role. Ramchurn et al. [16] developed a trust model based on confidence and reputation. It makes use of fuzzy techniques to guide agents in evaluating past interactions and in establishing new contracts with one another. Huynh et al. [7,8] described FIRE, which is a trust and reputation model. It integrates a number of information sources to produce a comprehensive assessment of an agent's likely performance in open systems. Victor et al. [20] advocate the use of a trust model in which trust scores are (trust, distrust)-couples. These scores are drawn from a bilattice that preserves valuable trust provenance information including gradual trust, distrust, ignorance, and inconsistency. Nguyen and Tran [13–15] introduced a computational model of trust, which is also combination of experience and reference trust by using fuzzy computational techniques and weighted aggregation operators. Katz and Golbeck [10] introduces a definition of trust suitable for use in Web-based social networks with a discussion of the properties that will influence its use in computation. Hang et al. [5] describes a new algebraic approach, shows some theoretical properties of it, and empirically evaluates it on two social network datasets. Guha et al. [4] develop a framework of trust propagation schemes, each of which may be appropriate in certain circumstances, and evaluate the schemes on a large trust network. Vogiatzis et al. [21] propose a probabilistic framework that models agent interactions as a Hidden Markov Model. Burnett et al. [1] describes a new approach, inspired by theories of human organisational behaviour, whereby agents generalise their experiences with known partners as stereotypes and apply these when evaluating new and unknown partners. Hermoso et al. [6] present a coordination artifact which can be used by agents in an open multi-agent system to take more informed decisions regarding partner selection, and thus to improve their individual utilities.

However, the current models fail to deal with the situation of a new entrant trustee, in which there is neither the experience trust nor the reputation of the trustee to refer. A question is how does a truster agent estimate some trust value about the given trustee in the situation? Intuitively, a simple solution for initiation of trust in this situation is assigning a random value for the trust of the new coming trustee. This will be fine if the model is applied to the application which has many contacts/transactions between trusters and trustees. Because this initial value of trust will be rapidly updated by the experience trust from contacts/transactions. Conversely, in the applications where the number of transactions are small, the initial value of trust will strongly affect on the lifetime of the overall trust of a trustee. Therefore, it is better to avoid the random initial value. In order to overcome this limitation, we could use other information resource such as profile, and/or other personal data about new coming trustee to compare with a well known other trustee by solving the following issues:

First, if an agent A has a well known trust on agent B with a value of x, and that the similarity level on profile between agent B and a new coming agent C is y. How much should the initial trust of agent A on agent C be assigned?

Second, in the case an agent A has the well known trusts on a set of agents $\{B_1, B_2, ...B_n\}$, with respective values $\{x_1, x_2, ...x_n\}$, and that the similarity level on profile between each agent B_i and a new coming agent C is y_i. How much should the initial trust of agent A on agent C be assigned?

In this paper, we first propose a new mechanism for trust propagation which is based on the similarity of a new trustee profile and the other well known ones. Then we describe a weighted combination model for integrating types of experience trust, reputation and similar trust. The remainder of the paper is structured as follows. Section 2 presents the similarity based mechanism for trust propagation. Conclusion is presented in Sect. 3.

2 Similarity-Based Mechanism for Trust Propagation

In this model, we distinguish three types of trust among agents in multiagent systems:

- *Experience trust*: the trust that a truster obtained based on the history of interaction with a trustee. An interaction is called a *transaction*, and trust from the interaction is called *transaction trust*.
- *Similar trust*: the trust that a truster obtained by reasoning itself on the similarity of a trustee with other well known trustees. A trustee is considered as *well known* with a truster if there is an interaction between the truster and the trustee and the truster has its own experience trust about this trustee.
- *Reputation*: the trust about a trustee that a truster refers from other agents in the system. We assume that agents are willing and trustworthy to share their experience trust about some trustee to other agents.

Let $A = \{1, 2, ...n\}$ be a set of agents in the system and denote E_{ij}, S_{ij}, R_{ij} and T_{ij} to be the experience trust, the similar trust, the reputation and the overall trust that agent i obtains on agent j, respectively. The following subsections will describe a computational model to estimate the values of E_{ij}, S_{ij}, R_{ij} and T_{ij}. Subsection 2.1 presents the experience trust. Subsection 2.2 presents the similar trust. Section 2.3 presents reputation. Section 2.4 presents the overall trust of a truster about a trustee.

2.1 Experience Trust

Intuitively, experience trust of agent i on agent j is the trustworthiness about j that agent i collects from all transactions between i and j in the past. Let U_{ij} be a set of transactions having been performed between agent i and agent j until the current time.

Experience trust of agent i in agent j, denoted as E_{ij}, is defined by the formula:

$$E_{ij}(t_{ij}, w) = \sum_{k=1}^{|U_{ij}|} t_{ij}^k * w_k \tag{1}$$

where:

- t_{ij} is the vector of transaction trust of agent i in its partner j: $t_{ij} = (t_{ij}^k)$, $k = 1, ..., \mid U_{ij} \mid$ and $i, j = 1, ..., n$. $t_{ij}^k \in [0, 1]$ is the trustworthiness of agent i about agent j from the k^{th} latest transaction between i and j.
- $w = (w_1, w_2, ...w_{|U_{ij}|})^T$ is called the transaction weight vector if $w_k \in [0, 1]$, $k = 1, ..., \mid U_{ij} \mid$, is the weight of the k^{th} latest transaction based on agent i evaluation such that:

$$\begin{cases} w_{k_1} \geqslant w_{k_2} \text{ if } k_1 < k_2 \\ \sum_{k=1}^{|U_{ij}|} w_k = 1 \end{cases} \tag{2}$$

The weight vector is decreasing from the head to the tail of the sequence since the aggregation focuses more on the later transactions and less on the older transactions. It means that the later the transaction is, the more its trust is important to estimate the experience trust of the correspondent partner. This vector may be computed by means of Regular Decreasing Monotone (RDM) linguistic quantifier Q (Zadeh [25]) as a function $Q : [0, 1] \to [0, 1]$ which satisfies the following conditions:

(i) $Q(0) = 1$;
(ii) $Q(1) = 0$;
(iii) $Q(i_1) \geqslant Q(i_2)$ if $i_1 < i_2$.

For example, the following functions are RDM functions:

(i) $Q(x) = (1 - x)^m$ with $m \geq 1$
(ii) $Q(x) = 1 - \sqrt{1 - (1 - x)^2}$

And then, the vector w_i, which is defined by the following formula, is the transaction weight vector:

$$w_i = Q\left(\frac{i-1}{\mid U_{ij} \mid}\right) - Q\left(\frac{i}{\mid U_{ij} \mid}\right) \text{ for } i = 1, ..., \mid U_{ij} \mid$$

2.2 Similar Trust

Similar trust is the trust that a truster obtained by reasoning itself on the similarity of a trustee with other well known trustees. Without loss of generality, we assume that there are n concerned characteristics $\{a^1, a^2, ...a^n\}$, which are objects or attributes of some object, to measure the similarity between two agents. There are several methods to measure the similarity between two objects (cf. D. Lin [11]). In order to keep our model as simple as possible, we use *distance* between two agents based on a weighted average operator over the differences on the evaluation of characteristics given by these agents. For the sake of computation, results in evaluation are usually normalized into values of the unit interval $[0,1]$. And then from now on, we only consider normalized values which given by agents in the system.

Definition 1. *Suppose that* a_i^k a_j^k *are two normalized values on the characteristics* a^k*, which have been evaluated by agent* i *and agent* j*, respectively. The difference between agent* i *and agent* j *(*$i,j \in A$*) on characteristics* a^k *is defined by the formula:*

$$d_{ij}^k = \mid a_i^k - a_j^k \mid \tag{3}$$

The difference between two agents is then estimated by averaging the difference between them on all considered characteristics:

Definition 2. *The difference between agent* i *and agent* j *(*$i,j \in A$*) is defined by the function* $f_d : [0,1]^n \rightarrow [0,1]$*, which is a mapping from the differences on all considered characteristics into the overall difference between them:*

$$d_{ij} = \frac{\sum_{k=1}^{n} w^k * d_{ij}^k}{\sum_{k=1}^{n} w^k} \tag{4}$$

where w^k, d_{ij}^k *are respectively the weight of the characteristics* a^k *and the difference on the attribute* a^k *between agent* i *and agent* j*.*

The estimation of similar trust of truster i about trustee j via another trustee l is based on the combination of the experience trust of i about l, and the difference between l and j. Intuitively, this combination must satisfy the following conditions:

- The more the experience trust of i about l is high, the more the similar trust is high;
- The more the difference between l and j is low, the more the similar trust is close to the experience trust of the well known trustee.

These constraints may be represented by the following *Similar Trust Function - STF*:

Definition 3. *A function* $t_s : [0,1]^2 \rightarrow [0,1]$ *is called the similar trust function, denote STF, if and only if it satisfies the following conditions:*

$$(i).\ t(e_1, d) \leqslant t(e_2, d) \ \textit{if}\ e_1 \leqslant e_2;$$
$$(ii).\ \mid e - t(e, d_1) \mid \leqslant \mid e - t(e, d_2) \mid \ \textit{if}\ d_1 \leqslant d_2;$$

It is easy to prove the following proposition.

Proposition 1. *The following functions are STF functions:*

(i). $s(e,d) = \begin{cases} e + d * (1-e) & \text{if } e < 0.5 \\ e - d * e & \text{if } e \geq 0.5 \end{cases}$

(ii). $s(e,d) = \begin{cases} e - d * e & \text{if } e < 0.5 \\ e + d * (1-e) & \text{if } e \geq 0.5 \end{cases}$

Now we can define the individual similar trust of a truster i about a trustee j via the similarity between the trustee j and another trustee l as follows.

Definition 4. *The individual similar trust of a truster i about a trustee j via the similarity between the trustee j and another trustee l is a function $f_s : [0,1] \times [0,1] \rightarrow [0,1]$ from the experience trust of truster i about trustee l and the difference between trustee l and trustee j defined as follows:*

$$s_{ij}^{l} = f_s(E_{il}, d_{lj}) \tag{5}$$

where f_s is a STF function, E_{il} is the experience trust of truster i on trustee l, d_{lj} is the difference between agent j and agent l.

Based on the concept of the individual similar trust, we can now define the similarity trust via a set of trustee agents. Let $O \subseteq A$ be the set of all agents who have already executed at least one transaction with agent i. The similar trust of truster i about trustee j via all well known trustee $k \in O$ of the truster i is then defined as follows:

Definition 5. *The similar trust of truster i about trustee j in general is a function: $[0,1]^{|O|} \rightarrow [0,1]$ from all individual similar trust of truster i about trustee j via trustee $k \in O$:*

$$S_{ij} = \frac{\sum_{k=1}^{|O|} n_k * s_{ij}^{k}}{\sum_{k=1}^{|O|} n_k} \tag{6}$$

where s_{ij}^{k} is the individual similar trust of truster i on trustee j via trustee k, n_k is the number of transactions made between agent i and agent k.

2.3 Reputation

Reputation of agent j is the trustworthiness on agent j given by other agents in the system. We share the point of view given by Huynh et al. [8] who suppose that any agent in the system is willing and trustworthy to share its experience trust a bout a particular trustee to other agents.

Suppose that j is an agent which the agent i has not yet interacted with but needs to evaluate to cooperate with. Let $V_{ij} \subseteq A$ be a set of agents that an agent i knows and have had transactions with j in the past.

Reference trust of agent i on agent j:

$$R_{ij} = \begin{cases} \dfrac{\sum\limits_{l \in V_{ij}} r_{ij}^{l}}{\mid V_{ij} \mid} & \text{if } V_{ij} \neq \varnothing \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

where r_{ij}^{l} the individual reference trust of agent i on agent j via agents l ($l \in V_{ij}$), $r_{ij}^{k} = E_{kj}$, E_{kj} is the current experience trust of k on j.

2.4 Overall Trust

Resulting from these partial trust measures, we may construct a definition of combination of these types of trust.

Combination trust T_{ij} of agent i on agent j is defined by the formula:

$$T_{ij} = w_{ie} * E_{ij} + w_{is} * S_{ij} + w_{ir} * R_{ij} \tag{8}$$

where E_{ij}, S_{ij}, R_{ij} are experience trust, similar trust and reputation about trustee j in the point of view of truster i, respectively and $w_{ie} + w_{is} + w_{ir} = 1$ are weights of these trusts.

3 Conclusion

In this paper, we have introduced a new mechanism for trust propagation which is based on the similarity of a new trustee profile and the other well known agent ones. The trust inferred from similar computation mechanism has been combined in the weighted computation with the experience trust and reputation to achieve an overall trust. In our work, all agents are supposed to be faithful. It means that they always provide reliable information for computing reputation and similarity. However, in the reality, there may be some lying agents who intend to provide unreliable information for the sake of their own utility. Dealing with the situation when considering similar trust and reputation with such unreliable information of liars will be our future research topics. The research results will be presented in the other work.

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