A Computational Model of Trust

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Abstract.

A computational trust model is constructed from the viewpoint of the elements that affect trust in this paper. In this model, 3 types of trust: basic trust, recommendation trust, interaction trust, and 4 kinds of relationships between two entities in a trust system are considered. By analyzing the elements that influence trust, such as time, situation, and the role of the entity trust in, and so on, the trust model is given. Then, the trust value about a main entity trust in an object entity can be calculated, and the main entity can adjust trust value over time.

1 Introduction

Trust is a very important feature of human life undoubtedly. Trust management and its applications become a steadily growing research field. In the past years, the main work of trust came from sociology, social psychology, and philosophy [1-4]. With the development of computer and network, trust in network should be noticed. In a web-based system, there are many entities that need to interact with one another. They act in an autonomous and flexible manner. They are likely to be unreliable, and maybe know nothing about each other. In order to facilitate interactions in such systems, trust must be addressed. So trust is also important to effective interactions in web-based systems that have much in common with human society.

Up to now, there are many different definitions and models about trust, such as Beth’s model using direct and recommendation trust [5], Manchala’s model using fuzzy logic [6], Jøsang’s model using subjective logic [7], and so on. Why are there so many different definitions about trust? Because “definitions vary depending on the researcher’s background, outlook on life and the application domain of the problem being solved. [8]”

From the viewpoint of research method, there are two main methods to study trust. One is qualitative, the other is quantitative. The qualitative method is to find the elements that affect trust and give an orally explanation to resolve it [9,10]. The quantitative method is to give a computable model for trust in a special field. Generally, for the sake of formalize and computable, the model is always simplified through deleting some variables [11-14].

In this paper, we give a computational trust model with some certain computation. In this trust model, we consider has 3 types of trust: basic trust, recommendation trust, interaction trust; and classify the relationships between trustor and trustee into 4 kinds according to if there are recommendation and direct interaction between them. By analyzing the elements that influence trust (such as time, situation, the role of the trustee), we get the trust model. Furthermore, the trust value from trustor to trustee can be calculated through the basic trust of the trustor.

The paper is organized as follows. Section 2 gives the basic concepts and involved contents of the computational trust model. Section 3 gives the computational trust model. Finally, section 4 concludes the paper.

2 The Basis of the Computational Trust Model

The involved contents in our trust model, including 3 kinds of trust, similarity of situations, and the role of the trustee, will be explained in this section.

2.1 3 Kinds of Trust

3 kinds of trust we study are basic trust, recommendation trust, and interaction trust respectively. We explain them one by one in the following.

In [15], Boon, S.D. and Holmes, J.G. proposed that an entity has a “basic” trust, which is derived from past experience in all situations, and has a value in the range [-1,+1]. Good experiences lead to a greater disposition to trust, and vice versa. Marsh S.P. [4] developed this idea in his PhD thesis. In fact, the basic trust of an entity embodies its trusting disposition. We argue that the proposal of this concept is very important, and it is the basis of an entity affiliating with others. In this paper, we define the value of basic trust in the range [0,1]. The basic trust of an entity *x* is denoted by BT_x. We assume that an entity's basic trust is a fixed value during a period of time. In a real world, there are three kinds of people in a trust system. They are optimists ($BT_x \geq 0.5$) which prefer trust in others, pessimists ($BT_x \leq 0.5$) which prefer distrust in others, and realists ($BT_x = 0.5$). Of course, the classification may not be so strict. For example, if BT_x is in [0.4,0.6] in the real world, we may say *x* is a realist.

In [5], Beth, T. proposed 2 types of trust: direct and recommendation trust. "To trust an entity directly means to believe in its capabilities with respect to the given trust class. Recommendation trust expresses the belief in the capability of an entity to decide whether another entity is reliable in the given trust class and in its honesty when recommending third entities." Using the idea similar to Beth's direct and recommendation trust, we consider the interaction trust and the recommendation trust. But our meanings are different from that of Beth. In our paper, interaction trust means the trust that trustor trust in trustee when they have direct interactions; recommendation trust is the trust about trustee provided by the third entity to trustor. We should notice that the recommendation trust the third entity provides trustor may not be the real value of interaction trust between it and trustee. That is to say, cheat and false suggestion would be given to the trustor. So, generally speaking, accepting recommendation trust should be with some discount.

2.2 Similarity of Situations

Trust management is always connected with some certain context. For example, while I may trust my dentist to fill a tooth, I would not trust him to operate on my heart, and I most certainly would not trust him to drive a plane from Hongkong to New York. So, different situations affect necessarily trustor's trust in trustee. But, as we know, there are some similarities between filling a tooth and operating on the heart. At least they are operated in the hospital and the operators are all doctors. Whereas, there is no any similarities between filling a tooth and driving a plane. So, it is necessary to describe the similarity of situation. If we haven't some trust information under a special situation, we can consider its similar situation and obtain relevant information. Here, we should have a penalty factor to discount the similarity.

A situation can be described by some useful attributes, such as, time, place, action, attendee, topic, furnishings, tools, etc. For the sake of clearity, we use a tuple $\alpha = (a_1, a_2, ..., a_m)$ to represent a situation whose number of attributes is *m*, and each attribute a_i belongs to {0,1}. For two situations, we use similarity coefficient between them to show their similarity, which is defined as:

$$r = \frac{n_1}{n_1 + n_2}$$

In which, n_1 means the number of attributes whose values are equal, n_2 means the number of attributes whose values are not equal, n_1+n_2 means the number of all the attributes. It is clear that $r \in [0,1]$. The larger *r* is, the stronger similarity is. If similarity coefficient of two situations is larger than a given threshold value, we say they are similar, and denoted by $\alpha : \beta$. For example, α and β are two situations with 10 same attributes. Their values are α=(0,1,1,0,1,0,0,1,1,0) and β=(0,1,0,0,1,1,0,1,0,0) respectively. So, the similarity coefficient between them is *r*=6/10.

2.3 Role of Trustee

In the above example about filling a tooth, if there are two people to be selected to do this operation: one is a dentist, the other is a driver, I think anyone who considers his safety and life will choose the dentist to fill his tooth. Because a dentist can obtain more trust than a driver in this situation. It is evident that the trustee's role affects the trustor's trust in him. So, we should consider the role of trustee in a trust system.

The role of a trustee under a situation should be an objective value, which would not be changed because of different trustors. We suppose that the role value is in [0,1]. If the trustee is suitable for a situation, its role value should be large. For example, in the above example about filling a tooth, the role of dentist may be 0.95, that of driver may be 0.03, and that of cardiologist may be 0.3.

3 Computational Trust Model

In order to describe our model clearly, we give some assumptions firstly, and then discuss the computational model.

Assumptions:

1. The recommendation trust of the intermediate entity is only considered under the same situation as the trustor considered.

2. For recommendation trust, there is a penalty factor which is correlated with the basic trust of trustor.

3. There is only one intermediate entity between trustor and trustee.

4. Only such entity that has direct interactions with the trustee can be the third entity to provide trustor recommendation trust.

In our computational trust model, we consider 4 types of circumstances in a trust system between two entities *x* and *y*. The circumstances are classified into 4 kinds according to if there are recommendation and/or direct interaction between them. In this section, we will study these different relation through analyzing the correlated elements affecting trust to obtain the final estimator of $T^n_{\alpha,x}(y)$, trust value of trustee *y* from trustor *x* at time t_n under the situation α.

Suppose *x* is a trustor, *y* is a trustee, and *A* is a third entity to provide recommendation trust of *y* to *x*. Let *Rec*=1(or 0) represent there is (not) an intermediate entity *z* between *x* and *y* under the situation α, *Int*=1 (or 0) represent there are (not) interactions between *x* and *y* under the situation α. Then, the 4 kinds of relationships can be described as: 1. *Rec*=0, *Int*=0; 2. *Rec*=1, *Int*=0; 3. *Rec*=0, *Int*=1; 4. *Rec*=1, *Int*=1. We analyze them one by one.

1. ***Rec*=0, *Int*=0**. It means that there have no not only recommendations but also interactions between *x* and *y*. Such circumstance show that trustor *x* has no any information about trustee *y* under the situation α. So, we can consider if there are similar situations β_i that can provide us useful information. Through analyzing the correlated elements, we get the following formula.

$$T^n_{\alpha,x}(y) = f_{(0,0)}(BT_x, R_\alpha(y), T^n_{\beta_i,x}(y), P_s) \qquad (1)$$

Where, P_s is penalty factor caused by similarity of situations, $R_\alpha(y)$ is role of trustee *y* under the situation α.

2. ***Rec*=1, *Int*=0**. It means there is an intermediate *A* between *x* and *y*, and there are no direct interactions between them. In this circumstance, trust value from trustor *x* to trustee *y* can be obtained only through its basic trust BT_x and the recommendation of *A*. There are many factors affecting the trust value. Such as, role of trustee *y* under the situation α, trust value of trustee *A* from trustor *x* at time t_n under the situation α, recommendation trust value of *y* from *A* at time t_n under the situation α, etc. At the same time, because the recommendation may be unreal, there should be a penalty factor P_r to control it. So, we give the following formula to describe the trust value.

$$T^n_{\alpha,x}(y) = f_{(1,0)}(BT_x, R_\alpha(y), A, P_r, T^n_{\alpha,x}(A), RT^n_{\alpha,A}(y)) \qquad (2)$$

Where, $RT^n_{\alpha,A}(y)$ is recommendation trust value of *y* from *A* at time t_n under the situation α.

3. ***Rec*=0, *Int*=1**. Since there are only interactions and no recommendations between *x* and *y* under the situation α, we can but consider their direct interactions to model. Suppose t_{n-1} is the time of last interaction between *x* and *y* under the situation α, and $\Delta t = t_n - t_{n-1}$. As we know, the longer Δt is, the smaller the trust is. It is evident that Δt affects the trust value necessarily. So, we have the following function, which is decreasing as Δt increases.

$$T^{n}_{\alpha,x}(y) = f_{(0,1)}(BT_x, R_\alpha(y), \Delta t, T^{n-1}_{\alpha,x}(y)) \qquad (3)$$

4. ***Rec*=1, *Int*=1**. Here, there have not only an intermediate entity *A* but also direct interactions between *x* and *y* under the situation α . It will be taken as the combination of circumstance (0,1) and (1,0).

$$T^{n}_{\alpha,x}(y) = f_{(1,1)}(BT_x, R_\alpha(y), \Delta t, T^{n-1}_{\alpha,x}(y), A, P_r, T^{n}_{\alpha,x}(A), RT^{n}_{\alpha,A}(y)) \qquad (4)$$

About the calculability of this model, which is correlated with the basic trust of the trustor *x*. Here, we take BT_x=0.5 as an example to explain it. BT_x =0.5 means that an arbitrary stranger is indifferent in trustor *x*'s mind. Trusting or distrusting is depend on subsequent interaction and other's recommendation. So, the initial value of $T^{0}_{\alpha,x}(y)$ is 0.5. We give the function $f_{(0,0)}$ as following:

$$T^{n}_{\alpha,x}(y) = T^{n}_{\beta_i,x}(y) \times P_s \qquad (5)$$

In which, BT_x, $R_\alpha(y)$ are hidden in $T^{n}_{\beta_i,x}(y)$.

4 Conclusions

We proposed a computational trust model based on 3 types of trust and 4 kinds of relationship between trustor and trustee in this paper. This model has the following characteristics: it considered time to make the model dynamic; it considered situation and the role of trustee to make the model realistic; it considered penalty factor to control the unreal recommendation; it considered the difference between trustor and trustee to embody the asymmetry of trust.

But there still exist many problems to be resolved. For example, how to measure the initial properties of trust; how to examine unreal recommendation; how to find a proper calculate method to avoid the fact that the trust value is more and more of small because of product, and so on. These work are worth to be studied in the future.

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