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# Behavior-aware Trust Reasoning Based on Associate Petri Net

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**Abstract:** Trust issue is an important problem both in social field and in information field. In the study, behavior-aware trust reasoning methods based on Associate Petri Net (APN) are presented. Firstly, a task is planed by the activities and their collaborating relationships. Then, taking advantage of APN to turn every activity into a local trust model, which forms global trust model by certain dependent relationships, between these local trust models, their interaction relationships are taken into account, the trust value of local trust model is adjusted according to the interaction relationships. Finally, using Discrete Particle Swarm Optimization (DPSO) combined with the properties of APN, through APN reasoning rules, the optimal trust value of total task can be obtained. Theoretical analysis and experimental results indicate that this method owns both lower computation cost and lower error rate.

**Key words:** Trust, behavior, petri net, modeling, discrete particle swarm optimization

## INTRODUCTION

Trust issue is an important problem both in social field and in information field and it is a cognitive phenomenon of human society, which can reflect the basic belief of an individual to human nature. In social network, trust relationship is the core of interpersonal relationship and the trust relationships dependent on each other constitute the so-called web of trust (Mogens *et al*., 2007).

The researches related to trust are the main emphasis in social science field all the time, but they paid more attention to the qualitative research in the field of humanities. On the whole, for a long time trust is looked as a cognitive phenomenon, which is subjective, imprecise and unreliable, even is distrusted. Therefore, scientific and systematic researches about trust are lacked, most of all, it lacks the formal and quantitative research. With the open network represented by Internet arising and developing, it becomes more and more urgent to study trust by formal method (Yin *et al*., 2010).

Trust is divided into identity trust and behavior trust and only identity trust is considered in the typical security, which mainly involves the identity authentication of user and server and resource access control after authorized. Behavior trust is defined as the evaluation of behavior coming from the interaction among two or more entities. Modeling the behavior trust of an entity is aim to study how to formally define, evaluate and deduce the trust level in open network environment (El-Salamouny *et al*., 2009).

Diego (1990) defined the trust by mathematics method for the first time and trust is defined as the subjective possibility prediction of object's specific behavior from subject, which depends on the experience and will be revised continuously along with the variance of object's behavior result. The definition reflects the uncertainty of trust and lays the theoretical foundation for the representation of trust by mathematics method.

Theodorakopoulos and Baras (2006) interpret the concept of trust as a relation among entities that participate in various protocols. Trust relations are based on evidence created by the previous interactions of entities within a protocol. The evaluation process is modeled as a path problem on a directed graph, where nodes represent entities and edges represent trust relations. Using the theory of semirings, the paper shows how two nodes can establish an indirect trust relation without previous direct interaction. Adnane *et al*. (2008) proposed for OLSR the integration of trust reasoning into each node behavior, so as to allow a self-organized trust-based control to help nodes to detect misbehavior attacks. The analysis of OLSR brings out the trust rules that characterize this protocol and allows us to express formally the trust-related properties that can be verified by each node to assess the correct behavior of the other nodes. Simulation of OLSR with nodes reasoning on trust allows us to demonstrate the effectiveness of our approach and to compare trust-based routing choices with the bare OLSR reachability-based choices. Ray *et al*. (2009) proposed a model that allows us to formalize trust relationships, the trust

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relationship between a truster and a trustee is associated with a context and depends on the experience, knowledge and recommendation that the truster has with respect to the trustee in the given context. Sometimes enough information is not available about a given context to evaluate trust, formalizing the relationships between contexts allows us to extrapolate values from related contexts to approximate the trust of an entity even when all the information needed to calculate the trust is not available (Ray *et al*., 2009).

The methods mentioned above didn't consider the behavior interaction between participants, while in the process of interaction between different local trust models, some special interaction behavior relationships may arise, such as behavior consistent relativity, behavior exclusion relativity, behavior interaction relativity, behavior controlled relativity. And for the different interaction property, there is different effect on the computation of trust. In this study, on the basis of analyzing the computing method of trust degree, associated Petri net is used to model the local trust model. Furthermore, combined with the behavior interaction relationships, computation policies about trust degree are presented aimed to different behavior relationships. At last, Discrete Particle Swarm Optimization (DPSO) is used to find the optimal trust value.

## BEHAVIOR MODELING METHODS TRUST REASONING BASED ON APN

The concept of trust originally derives from sociology, so it possesses the subjectivity, generality and so on and the trust concept in sociology is not applicable for the user's behavior trust in science. Therefore, we decompose user's whole behavior trust step by step according to practical application requirements and functional characteristics, in detail, the comprehensive and general behavior trust can be decomposed into several behavior trust attributes, in Fig. 1. By means of this method the role can easily evaluate the trust attributes and the problem of generality and uncertainty of user's behavior trust can be resolved effectively. For example, user's behavior trust can be decomposed into security trust attribute, performance trust attribute and reliability trust attribute and so on.

There are some related researches about trust modeling and trust reasoning, for example, Bayes network model (Mogens *et al*., 2007) and based on it the probability of every node can be gotten through forward or backward reasoning. The modeling method not only owns theory foundation but also combines knowledge representation and knowledge reasoning together. On the

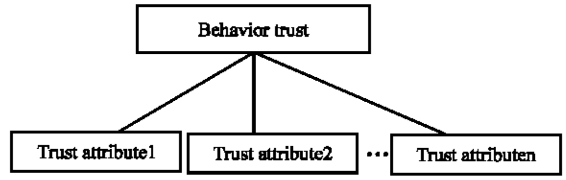


Fig. 1: Behavior trust attributes

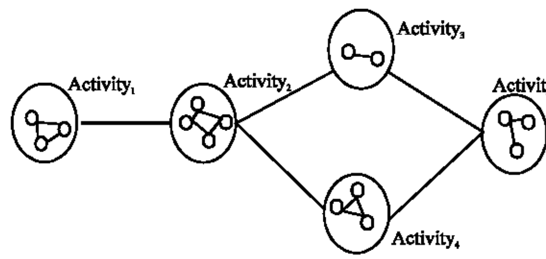


Fig. 2: Task activity graph (roles collaborating in activity)

one hand, the causal knowledge about the prediction of user's behavior trust can be expressed naturally and intuitively by directed graph. On the other hand, static data about user' behavior can be blended into the Bayes model in the form of condition probability. Thus, Bayes network can integrate the prior knowledge and posterior data seamlessly, which are all used to represent user's behavior, but it has also the limitation which does not consider the behavior interaction relationship between different roles, thereby, it makes the reasoning about trust more distrusted.

The proposed approach models a specify task by the APN (Shih *et al*., 2007). A task is composed of some activity with certain constraint relationships. Every activity is accomplished by several roles in Fig. 2, so we use APN to model every activity (called as local trust model), then these local trust model compose the global trust model by certain constraint relationships. In local trust model, the place nodes of the APN model represent the candidate roles, the support nodes represent constraint behavior attribute relationships between interaction roles and the transition nodes represent attribute trust value between interaction roles. The modeling methods about the trust evaluation of task based on the APN are presented as follows:

**Step 1:** According to the domain knowledge, a common task model including a series of activity and the dependent relation between activities is built by the expert personnel, the task model including activities and the dependent relation between activities

**Step 2:** A role modeling method by APN in Fig. 3

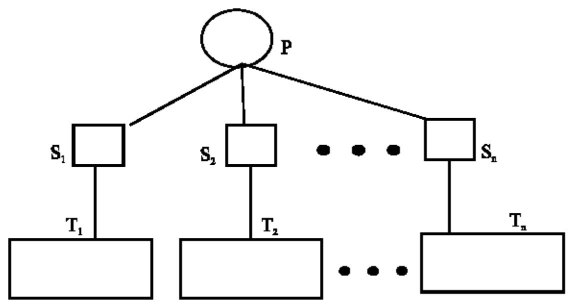


Fig. 3: APN model of a role

**Step 3:** For each activity in the task, locate dynamically roles (here, the roles may be either person or resource) which can accomplish the activity from all relative participant, every role is represented by the step 2, the roles collaborate to evaluate the trust value about the same activity are modeled as a local trust model

**Step 4:** In a local trust model, the constraint relationships between constraint attributes of roles are represented by support nodes. The threshold value $\tau$ of the support nodes are the constraint attribute value of the former role and the support value s is the constraint attribute value of the latter role (a series of roles accomplish the trust evaluation to the same activity by Recommended trust passing, the front role is called former role, the next is called latter role). If the s and $\tau$ satisfy the constraint relationship requirement (such as $s \geq \tau$, $s \leq \tau$ or $s \in \tau$ and so on), then the former role is linked with the latter role by directed arc

**Step 5:** In a local trust model, the associate relations between the roles which accomplish to evaluate the same activity trust value are represented by transition nodes, the threshold value $\gamma$ of the transition node is set by the practice needs (sometimes according to the overall situation of role trust value) and the trust value c is obtained by the data mining on the basis of the history calling relation between roles. So, an indirect trust link is built. If the c is less than $\gamma$, then the path from the former role to the latter role is not taken into account

**Step 6:** Between local trust models, we analyze the behavior relationships of the activity, because local trust model has been APN model. According to theorem 1, the behavior interaction relationship between two independent task component APN models mainly includes 4 kinds of category and for every interaction relationship, we will study the variation of trust value

- **Behavior consistent relativity:** All roles have no affection to each other in the interaction process and their behaviors are consistent before and after interaction, specially, in this paper the attribute values have no change after interaction
- **Behavior exclusion relativity:** It means for roles their behaviors are incompatible with each other and can not be interactive. Once they are exclusion all attribute values become zero
- **Behavior interactivity relativity:** It means after interaction some behaviors become inclusive and others are consistent. For the inclusive behavior, their attribute value can be obtained by minimum operator and other attribute values have no change
- **Behavior controlled relativity:** After interaction one role's behavior is controlled by the other, that is to say, in this case the attribute value of behavior controlled may be influenced behavior controlling. We using entire probability formula to compute the truth trust value of the controlled behavior and then determining the adjusted value

**Step 7:** Taking advantage of the step 1-6, an APN model can be obtained about entire task, which the interaction relationships are taken into account. The trust value of total task can be determined by the reasoning rules of APN

## EFFICIENT OPTIMIZATION ALGORITHM ABOUT SOLVING TRUST VALUE OF COMPLEX SYSTEM

For a complex system, lots of activities are needed and every activity needs some roles collaborating to accomplish the trust evaluation. When solving the trust value of total task, the time consuming is larger and error rate of the optimal trust value is higher. The paper makes full use of the properties of APN model, adopts DPSO methods (Fan *et al*., 2010) combined with APN. Concretely, regarding firing sequences of APN as chromosomes, every legal firing sequence in Petri Net model represent a feasible trust evaluation. It can make trust evaluation algorithm closely related to Petri Net models, which turns the problem of trust evaluation into the problem of searching for the best firing sequences based on the APN model. So the problem to be solved can be converted into the corresponding APN model, then the best firing sequence can be found by optimizing legal sequence with DPSO and in the searching process the problem can be tackled with the full use of the legal sequence algorithm of Petri net. If simply adopting Petri net (Murata, 1989) to do trust evaluation, it is very complex when the scale of model is comparatively large. If DPSO method is adopted only, searching has comparatively large randomness. It goes against resolving problems effectively. This method takes these two aspects into consideration simultaneously, which reduces the complication and searching randomness effectively.

The optimization methods solving trust evaluation of complex activity based DPSO and APN are as follows:

**Step 1:** **Initialize the particle population:** According to the requirement of total task, we select fixed number (such as K) firing sequences from APN model. If it exists a firing sequences $\sigma = p_1t_1p_2t_2p_3t_3 \cdots p_{n-1}t_{n-1}p_nt_n$, which makes $M_0[\sigma > M_f$, then $\sigma_p = p_1p_2 \cdots p_n$ (p is corresponding to the matching component services)can be regarded as a particle, here, $M_0$ is the first marking, $M_f$ is the end marking:

$$p_1, p_2, p_3, \cdots, p_{n-1}, p_n \in P,\ t_1, t_2, t_3, \cdots, t_{n-1}, t_n \in T$$

**Step 2:** For the initial population, computing the optimal best position $P_{id}$ of every particle and the global best position $P_{gd}$ of the all particle

**Step 3:** Computing the fitness value of every particle

**Step 4:** Computing ω, $c_1r_1$, $c_2r_2$, and sorting them from small to big

**Step 5:** Executing the substitution operation, for i = 1, i.e., for the freedom service, select the random place (component services) from the APN as the substitution, for i = 2 to n, select the brother place node of the place p as the substitution, then for j = i+1, select the legal firing path, in order to form a legal firing sequences (Changjun, 2001)

**Step 6:** According to:

$$v_{id}^{t+1} = \omega v_{id}^{t} \oplus c_1 r_{1d}(P_{id} - x_{id}) \oplus c_2 r_{2d}(P_{gd} - x_{id})$$

to compute the v.

**Step 7:** According to $x_{id}^{t+1}$ = substitute $x_{id}^{t+1}$, to compute the x

**Step 8:** For every particle, compute the fitness and update the optimal best position $P_{id}$ of every particle and the global best position $P_{gd}$ of the all particle

**Step 9:** Determining if the process traps in the local optimal solution, if the process traps in the local optimal solution, then executing the mutation operator (Fang *et al*., 2009), update the particles, goto step 3

## EXPERIMENT SIMULATION

In order to evaluate the proposed trust reasoning optimization algorithm, lots of experiments have been performed based on a series trust value of roles which are produced randomly.

The experiment is set as follows:

- A task has a series activity, there is has less than 5 roles to accomplish every activity and every role has 2 to 5 operation attributes
- The trust value is 0 to 1; the trust value may change with the context
- Experiment environment: CPU is Intel dual 1.60 GHz, Memory is 1.00 GB and operation system is Windows XP and MATLAB 6.5

Test 1 For a given task which satisfies above experiment set, using fuzzy trust computing methods (fuzzy trust computing methods) presented in the literature (Zhang *et al*., 2008) and the behavior-aware trust reasoning methods based on APN (behavior-aware trust reasoning methods) respectively, we compare their time efficiency under different activity number.

In Fig. 4, the experiment effect shows the execution time consuming of behavior-aware trust reasoning methods is less than the fuzzy trust computing methods, when the more of the activity number, the more obvious of the effect. The reason is that we uses fully APN's properties when DPSO locating in the APN model, which makes locating space lower and some roles which don't satisfy constraint relationships or have minor associate relation need not to match each other. So it can save execution time and improve the time performance of trust reasoning evaluation.

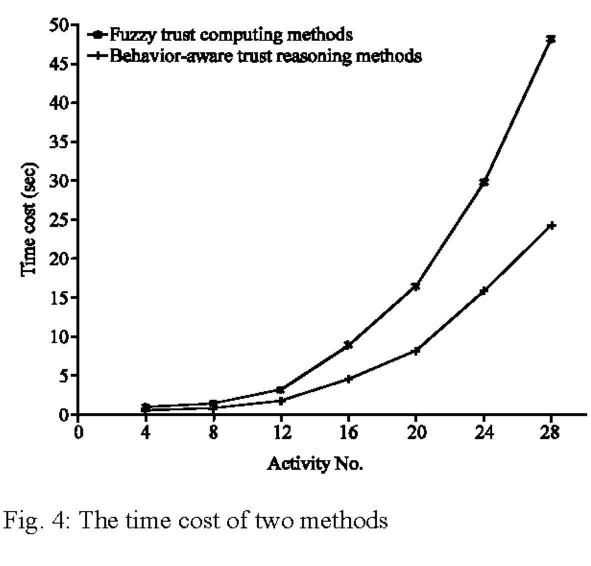


Fig. 4: The time cost of two methods

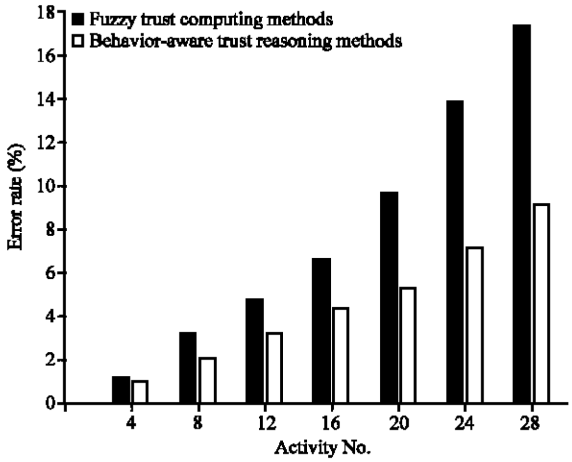


Fig. 5: The error rate of two methods

Test 2 For a given task which satisfies above experiment set, using fuzzy trust computing methods (fuzzy trust computing methods) presented in the literature (Zhang *et al*., 2008) and the behavior-aware trust reasoning methods based on APN (behavior-aware trust reasoning methods) respectively, we compare their error rate:

$$\text{Error rate} = \left( \frac{\text{Solving trust value-Optimization trust value}}{\text{Optimization trust value}} \right)$$

under different activity number.

In Fig. 5, the experiment effect shows the error rate of behavior-aware trust reasoning methods is lower than the fuzzy trust computing methods, in the behavior-aware trust reasoning methods, the behavior interaction relationships between the local trust model are taken into account, the trust value of some non-consistency relationships is adjusted, which can avoid the blindness according to the model simply to computing.

## CONCLUSIONS

The study presents behavior-aware trust reasoning based on APN. Firstly, a social task is planed several activities, every activity may be accomplished by a series of roles collaborating. Then, we use APN to model every activity for a local trust model, which forms global trust model by certain dependent relationships, between these local trust models, their interaction relationships are taken into account, according the theorem 1, 4 behavior interaction relationships such as consistency ,exclusion, controlled, interactivity, are analyzed, the trust value local trust model is adjusted. Finally, using DPSO combined with the properties of APN, through APN reasoning rules, the optimal trust value of total task can be obtained.

Based on the theoretical analysis and experimental results, the innovation and advantage of the study are:

- Behavior-aware trust reasoning based on APN is presented, in which the interaction behavior relationships are taken into account between local trust model
- A DPSO algorithm combined with APN is proposed, the algorithm can compute the global trust value quickly
- Compared with existing fuzzy trust computing methods, the methods proposed in the paper not only owns lower error rate but also lower computing cost

In the future, by analyzing some complex social or information issues, we plan to further study trust reasoning methods. Moreover, it is also one of our future works to study the behavior model of complex system.

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