AgentTMS: A MAS Trust Model based on Agent Social Relationship

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***Abstract*—Social relationships among Agents are natural, since Agents interact with each other when executing tasks. Diversity of the types and strengths of the social relationships influences the system policy of resource application and how Agents interact and cooperate with peers. AgentTMS is proposed by leveraging the Agent social relationships to improve the traditional trust models based on Agent's reputation and activity. Three types of Agent social relationships basing on biological relations, common social ties and business activity are defined and featured. The strength of the social relationships are measured and integrated into AgentTMS. The performance of AgentTMS is evaluated and validated by the presented results through considering the faster approach to the optimal resource allocation strategy. More detail here the initialization to the individual Agent and the effect to the rate of system reaching efficient state are about the result descriptions.**

***Index Terms*—MAS, Trust Model, Social Relationship**

I. INTRODUCTION

Your Intelligent Activity can be considered as a kind of social phenomenon, reflected by the sayings from the Minsky's "The Society of Mind" to the Gasser's "It must be established the basis of which multiple actors and their interaction is thought of as one basic-level category"[1]. Previous work showed the opportunity to investigate Multiple Agent System (MAS) and the intelligent activity from the sociological perspectives [2]. The principle of the social natures about the relationships of MAS, for example, the authority, the trust, the dependence and the support etc., is comparable to that of human beings. Like human's social interactions, Agents in MAS tend to present crowded activities such as cooperation, negotiation and their specified alliance, which reflect the similar modes compared with human[3].

Although Agents in MAS possess diverse social natures, generally, the social natures could be formalistically represented with the following forms: the occurring mechanism and regulation of various crowds' activity, the rationality of individual and crowds' activity [4]. According to the sociology theory, actor, resource, controlling relationships and benefit-based relationships constitute the basic elements of social activity system. In particular, actors exchange with peers with their controllable and significant secondary resources, which is called the sociability. In general, it is raised by the activity sociability, the harmony among Agents in MAS is thought as a fundamental problem [5]. Research in this paper is the issue of harmony among the Agents, in particular, partner selection and resource allocation issues.

A lot of work has been done in order to reduce interaction risk between Agents in open systems. Castelfranchi and Falcone considered the trust relation inside the MAS as a mental state, which is essential to permit delegation mechanisms between Agents [6]. Fullam et al., Griffiths also suggested that trust may be helpful to reduce the risk related to interactions between Agents [7]. Mui, Mohtashemi, and Halberstadt considered trust as a multidisciplinary subject and represented it as ontology. They classified trust definition into two types of directed and in-directed [8]. REGRET combined the models of direct and transitive trust and defined three Agent interaction dimensions (i.e., individual, social and ontological). In the individual dimension, trust is obtained by means of directed

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doi:10.4304/jcp.7.6.1535-1542

interaction, and for social dimension, trust is obtained by means of indirect interaction (i.e., testimony). While for the ontological dimension, trust is obtained with the combination of both [9]. Huynh proposed a trust model based on certified reputation, which combines both the direct and indirect trust (i.e., testimonies) [10].

MAS trust model has been studied mainly from the behavior and interaction of Agents, although some of the works introduced few relationship models to understand the trust relations transmission. However, they rarely considered the complex natural relations in MAS, which is of equal importance as the interactive behavior. We leverage three types of the complex and natural relationships in MAS to model the trust in MAS in this paper and try to bridge the gap in the area of MAS trust modeling based on social relationship. AgentTMS is introduced by combining the social relation model and the trust model, in which corresponding match is made for each pair of social relation model and trust model where the social relation model serves the trust model.

II. Trust Model

The concept of trust has different definitions. Dasgupta assumes that trust is the conviction that an Agent has about the fact that the actions declared by another Agent b will be effectively performed [11]. This characterizes an opportunity where b can attract for itself a higher rewarding. Ramchurn, Huynh, and Jennings state that trust represents the belief one has regarding the probity of someone else. This concept is necessary to the definition of interaction rules that keep a society (either of humans, animals or virtual systems like multi-Agent systems) [12]. Castelfranchi and Falcone define trust as a mental model that is part of a BDI Agent (believe, desire, and intention).There is a close relation between the concept of trust and multi-Agent systems. They assume that task delegation, essential in Agent collaborative work, is strongly related to trust [13].

Trust Model have been also researched, SPORAS [14] model is a famous concentrative trust model; every entity could give object Agent an estimate after interacts with it, and put the estimate in the knowledge database. Beth trust evaluation model [15] is given by the experience of trust leads to recommend the derivation and consolidated public Type. In Josang trust management model [16] provides a set of subjective logic operators, which is used in the calculation of trust between the operations. The main operators have merged operations (Conjunction), consensual (Consensus) and recommended (Recommendation). In Wang trust [17] model metrics, uncertainty and dependent on the number of interactive experience interactive and the proportion of success or failure experience. The trust evaluation model FIRE [18] considered a rich source of trust, the model expressed in the form of five-tuple (Interaction trust, Witness reputation, Role based trust, Certified reputation, Overall value). From these trust models mentioned above can be seen, the general trust model is mainly based on two aspects: the experience and simple transfer relationship. as closely as possible.

A. The Mathematical Description of Common Trust Model

In common trust model, it needs several elements to describe the capability of Agents and the update of this capability [19]. So it's introduced the three key elements as follow:

(1) Reputation Value (*R*), as an independent property value of each Agent, the reputation value changes with the Agent's social activities and interactions with others.

(2) Trust Value (*T*), it represents the total of other Agents' trust value to a certain Agent. This is a relative metric and would be affected by the Agent's own reputation value and the relationship with each other.

(3) The Credibility of Regulatory Factors (*p*) to adjust the value of the trust values. As the Agent participate in social activities, if the interactive success, the task is completed well, *p* is positive, Agent reputation value and trust value increases, and vice versa.

There are several formulas to describe the trust model as follow:

The trust value of Agent i to Agent j*:*

$$T_{i,j}(n) = \begin{cases} (1+p)\cdot T_{i,j}(n-1), & n \neq 1 \\ R_j(N), & n = 1 \end{cases} \quad (1)$$

The formula (1) shows that the trust value $T_{i,j}(n)$ is related to $T_{i,j}(n-1)$ after the last interaction, initial value is the *j* 's own reputation $R_j(N)$ before they have not interacted . And *p* is the adjustment factor for the trust value $T_{i,j}(n)$, it is described as equation (2):

$$p = \begin{cases} a, & p \in (0,1) \\ b, & p \in (-1,0) \end{cases} \qquad |a| < |b| \quad (2)$$

Such as (2) where *p* is for the credit adjustment factor that, and for the interaction after the adjustment of the relations between the two, when the successful interaction completed well, *p* is positive, the trust value increases, and vice versa. *a* is the increase step while *b* is the decrease step as the trust factor. According to the trust behavior of human beings, usually we let $|a| < |b|$, which implies that the decreasing rate of trust when Agents perform tasks unsuccessfully is larger than the increasing rate for Agents who successfully perform tasks.

Before they have not interacted, the trust value $T_{i,j}(n)$ lies on j 's own reputation $R_j(N)$, which is described as follow:

$$R_j(N) = R_0 \cdot (1+p) \cdot \ln N \quad (3)$$

The equation (3) shows that j*'s* reputation value and the credit regulator are related to the initial value of R_0 when it has not participated in any social activities. R_0 is initially assigned differently by different rules.

B.MAS trust model initialization and adjustment method

The proposed trust models in last section, its problems performed in the MAS are manifested in two aspects: (1) the single initialization to the individual Agent can not meet the demand for services; (2) the rate of system reaching steady state is low, it affects system operation results. Because there is no consideration the inherent natural links between Agents and these links are in the positive impact to complete tasks in the collaboration, negotiation, mutual choice and competition. The relationships between the roles of the trust model are in two ways, first is the initialization value of R_0 will be different for different relations between the two Agents. The second is the process of cooperation between the adjusted values which have the direct effect on trust value.

The k as the regulator of relationships between Agents is Introduced in the calculation

$$T_{i,j}(n) = k \cdot (1+p) \cdot T_{i,j}(n-1) \quad (4)$$

$k = 1 + \frac{1}{l}$, where l is the social value, it is the description of the relationships between the two Agents, the specific algorithm will be introduced in Trust Model based on Social Relationship.

C. The Rule of Resources Distribution and harmony

$$R_{ej} = \frac{T_{i,j}(n)}{\sum_{x=1}^{m} T_{i,x}(n)} \cdot R_{es} \quad (5)$$

The equation (5) presents the rules that how Agent i allocate resource to Agent j, and the proportional share based on the trust value. The R_{ej} is the share of resource allocated to the j Agent, while the R_{es} is the total amount of resource.

III. Trust Model based on Social Relationship

A.Social Relations

The nature of human is the summation of all the social relations which originate from human. Because there's humankind, the various complex relations are produced among the human-human, which collectively called social relation[20].

Leveraging these complex relations, a social relation model is abstracted and denoted as SRM, which is defined as following,

Definition 1: Social Relations

$SR = < K, S, B, K \cap S, K \cap B, S \cap B, K \cap S \cap B >$

In this definition, SR consists of three parts and the corresponding intersections, where K stands for Kin, S for Social Ties and B for Business Relationship.

(1) Kin Model

In SR, Kin are the son-Agents that Agents produce with different function on demand. Then it would produce a series of kin relationship groups. Because of the kin does not form the loop, the relationships could be represented by tree structure, as shown in Fig.1.

In the tree structure, there exist three types of Agent nodes: the uppermost node "r" is the root node in figure.1, the node "o" is the other node with children and one father, and the node has no child as seen the node "i" "j".

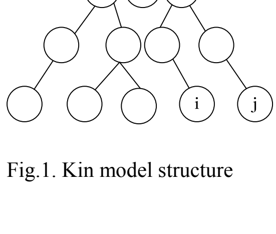


Fig.1. Kin model structure

The model has three features. First, the kin of Agents does not change with the time. Second, the parent Agent node for certain Agent is unique, and the third one is that the weight of each child Agent node to her parent Agent node is 1.

The key definition of the kin model:

(1) Blood relation: one of the natural relations of the kin. (2)Direct Blood Relative: another natural relation in kin namely the Agent's father and ancestor or the Agent's children and the off springs and so on. (3)Collateral Blood Relation: a non-direct blood relative within five hops in the relationship paths.

Kin Value(K_{ij})for a Agent pair i and j: if the two Agents have a ancestor, then the value K_{ij} should be the total number of hops from one Agent to another Agent through the ancestor, i.e., $K_{ij} = K_{io} + K_{oj}$, where the Agent o is the ancestor of Agent i and Agent j.

(2) Social Ties Model

Social Ties: As in the human society where we have classmates, colleagues, friends and other social relations, Agents have the similar relationships, which are well-known as social ties. Due to the bi-directional social relations, we use the weighted bi-directional and single-directional graph to express structure, as shown in Fig.2. This model has four features as follows. (1) It assumes the Agent social ties do not change over time. (2) The adjacent of an Agent note may not be unique. (3)The adjacent Agents are two-way or one-way relationship. (4) The weights for two nodes in each direction may be different.

The key definition of the Social Ties model:

1. Direct Social Ties: The relationship existed before contacting, it does not require any transmission and presentation of the social ties arising as a direct social ties.

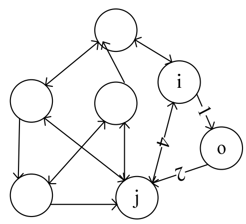


Fig.2 Social Ties model structure

2. Indirect Social Ties: The relationship did not exist before the interaction, as communication needs of other social relations are directly or indirectly, the object of social relations pass or introduce social relations arising as indirect social relationships.

Social Ties value (S_{ij}) for the Agent i and j is defined as the sum of weights in the shortest path between them, which is formulated as $S_{ij} = W_{io}S_{io} + ... + W_{oj}S_{oj}$. $l = S_{ij}$.

(3) Business Relationship Model

Business Relationship: the social interaction and relationship for mutual benefits of Agents is called as business relationship of Agents.

The key definition of the Business Relationship model:

1. Direct Business Relationship: The relationship existed before contacting; it does not require any transmission and presentation of the Business Relationship arising as a direct Business Relationship.

2. Indirect Business Relationship: The relationship did not exist before the interaction, as communication needs of other social relations are directly or indirectly, the object of social relations pass or introduce Business Relationship arising as an indirect Business Relationship. The relationship between the Agents will be enhanced with the increasing number of successful mutual cooperation and vice versa. Compared and differentiated with ST (Social Ties), the weight of Agents' business relationship changes with time. As the business relationship are bi-directional and may form the loop characteristics, we can use weighted bi-directional graph to represent their relationship diagram, as shown in Fig.3.

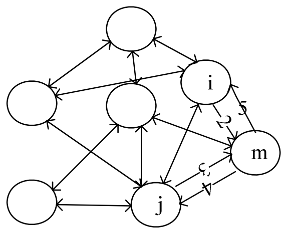


Fig.3 Business Relationship model structure

The model has three features: (1) the adjacent of an Agent note may not be unique. (2) The weights for two nodes in each direction may be different, and the smaller the weight, the more intimate for the relationship in that direction. (3) The adjacent Agents are all two-way relationship.

Social Business Relationship (B_{ij}) for the Agent i and j is defined as the sum of weights in the shortest path between them, which is formulated as $B_{ij} = W_{io}B_{io} + ... + W_{oj}B_{oj}$. $l = B_{ij}$.

(4) Diverse Relationships

Normally and naturally, it exists among Agents as human beings. At this sense, it is interesting and valuable to integrate Agents' relationships from different point of views so to fully represent the social interactions with the corresponding relationship strengths. As formulated as following, here we consider the three social relationships mentioned before. $l = L_{ij}$.

$$L_{ij} = \frac{1}{\frac{1}{K_{ij}} + \frac{1}{S_{ij}} + \frac{1}{B_{ij}}} \tag{6}$$

*K_{ij}, S_{ij}, B_{ij} are the optional objects

B. The Trust Value of Trust Model based Social Relations

Different social models have the corresponding trust model. Take the blood model as an example. The trust value of blood model between Agent i and j can be described by the equation (7):

$$T_{i,j}(n) = \begin{cases} (1+\frac{1}{l})\cdot(1+p)\cdot T_{i,j}(n-1), & l \in [1,5] \\ (1+p)\cdot T_{i,j}(n-1), & l \in (5,+\infty) \end{cases} \tag{7}$$

In the blood relationship, if i and j in the kin within 5 generations then $k=1+\frac{1}{l}$. But if l>5, their relationship strength would be processed as no blood relationship.

In social ties, their models are different. There are bi-directional and single-directional relationships. The smaller the weight w is, the more intimate the relationship is. The weight w is set as 1 for the node pairs of father and child, and for social ties relations, $1 < w < 10$. And the similar calculation method is as the same to kin model.

In the business relationship, the model is the bidirectional and weighted graph. The weight of business relationship ranges from 2 to 20, with the similar calculation method as kin model.

Ⅳ EXPERIMENT SETUP AND SIMULATION RESULT

A.Experiment Setup

To prove that the proposed trust model based on social relationship can play an enhanced role in AgentTMS MAS system, we use the lending behavior model to simulate the competition and collaboration of Agents in MAS. The borrowing part represents competition resources behavior, while being borrowed part represents the owners of resource to supply for the former. Trust model is used to control the resource distribution rules, so to expect the proposed model to outperform the common trust model.

In the experimental system we set V as the risk value which was produced after invested, which is randomly distributed in some investing Agent and decreases while the interactive successful ratio increases. Trust value T is figured out from the relation value R and their interaction times N, according to the active Agent deciding whether to lend to the passive Agent. With the increasing ratio of successful actions performed, the T increase as well, which makes sure that the priority is becoming higher. On the other hand, the Agents with low successful ratio would be washed out, so that the V will decrease while the social benefit increases.

Environmental Design system, as follows: it is supposed that there are *Y* Agents, each with ￥*K*. Active Agent will find some borrowers, through the accumulation of funds to achieve large-scale investment, and have a certain income (the revenue is proportional to its capacity, but there are also random failure rate of investment.) Agent role is divided into active and passive Agent. Active Agent: Agent takes the initiative to borrow money from other investors, who assumed active personal loans up to *X*. Active Agent capabilities: into 1, 2, 3 Level, Agent may determine borrowing capacity and the ability to gain skills. Passive Agent is the borrower's Agent, will be integrated passive borrowers who visit the active investment capacity and credit and other factors, to decide whether to lend money to those who take the initiative. Suppose passive borrowers can only borrow from one person, you may not borrow anyone.

Specific implementation schemes are designed as follows. (1) There are two values need to initialize: 1) the number of the active Agent borrowers' value *n*, and the number of the passive Agent borrowers' value *m*. In our experiment, the constraints for the two value are $n + m$ number $\leqq$ 1000 and $n \leqq m$. 2) the values of relationship strength of Agents to each other. (2) The output with common trust model is s_1 and with the trust model based on social relationship is s_2.

The design principle is as the Fig.4 and Fig.5 description:

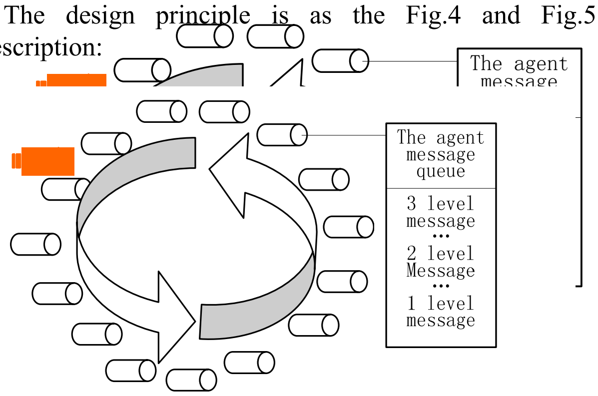


Fig.4. The experiment Setup design principle

After randomly distributing the passive Agents, the first Agent begins to the first round, to judge the Agents one by one, if it is the active Agent then send the borrowing message to the passive Agents. And the message will be queued in the passive Agents' message queues according to the priority of three level, the 3 level message is the upmost priority. The second round is to take out the massages and process them.

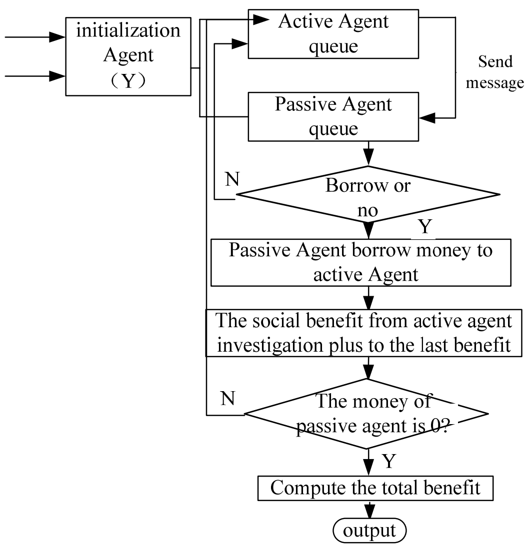


Fig.5. The workflow of the simulation experiment

The third round is to continue to process the borrowing messages, and compute society profit until the money of the passive Agent lend done, to get all the active Agents' money to produce the total social profit.

From the simulation experiment workflow shown as Fig.5, we can see the Program execution, firstly the Agents are divided two queues , one is the active agent queue and the other is passive agent queue, the formers give send message to the latter to borrow money. The passive Agents determine whether to borrow money to them, if borrow money to them, then the social benefit from active Agent investigation plus to the last benefit still the money of passive Agent is 0. Finally compute the total benefit and output.

B.Simulation Results

Based on the simulation platform, we need to prove AgentTMS to be available and predominant in the MAS: in the aspect of value randomly distributed generated the social benefits in the full polling, the results of introduction social relations into trust model should be better than the model without the introduction of social relation.

We will show the experiment results in the below pictures: Take the borrowing number 50 and 100 Random distribution values for example. To compare the effect of introduction of social relation in the difference of social benefit in a full polling.

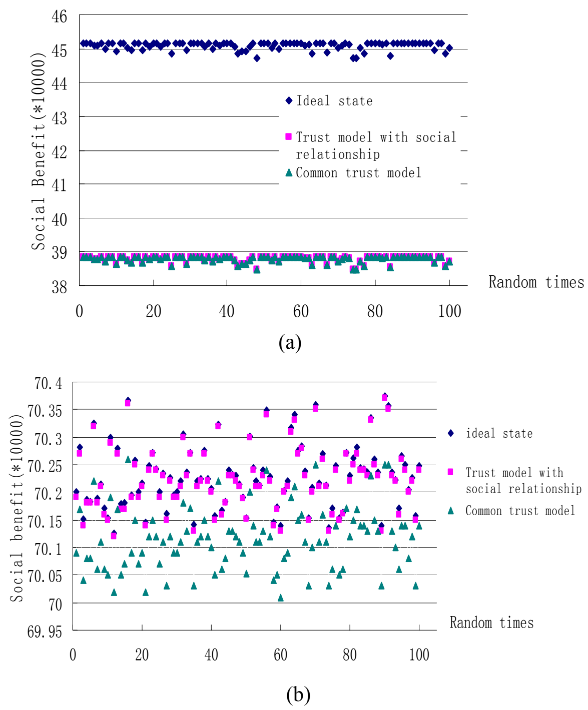
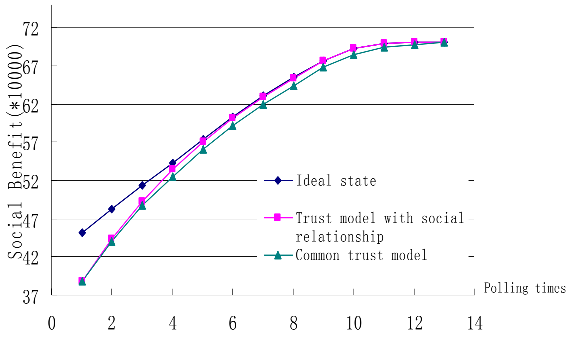
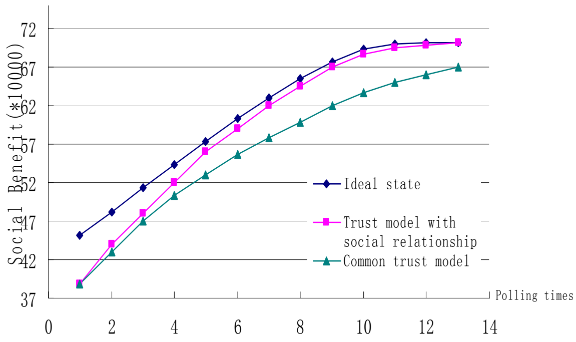


Fig.6. Social average benefits in 50 random distributions in the first polling and the last polling

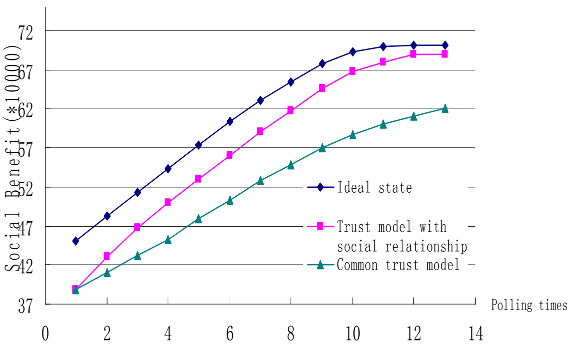
The Fig.6 (a) shows the beginnings state while the (b) shows the terminal state. In the beginnings state, the difference is very big, but in the terminal state it's almost consistent. Which shows in polling process, trust model with social relationship lets the social benefit close to risk-free ideal state social benefit finally. AgentTMS plays the key role to gradually reduce the risk to the minimum.



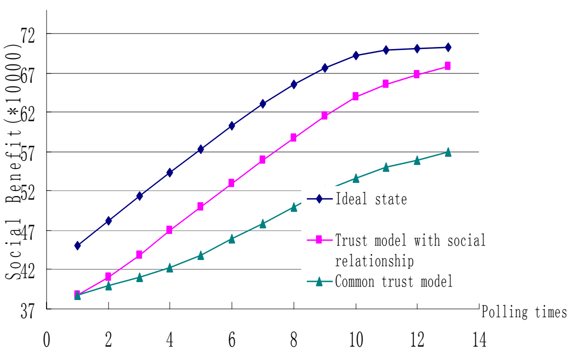
(a)



(b)



(c)



(d)

Fig.7. Social average benefits in 50 random distributions in the different failure ratio

In the different failure ratio of AgentTMS, the effect of the social relationship will be given to the experimental results as follow: Fig. 7 (a), (b), (c), (d) are the results to compare the social benefit of introduction social model and without the social model, the task failure ratios are separately 10%, 20%, 30%, 40% . We can see from the experimental results: firstly, in all the task failure ratios of circumstances, the proposed model of performance is more convergent to the ideal state than the common trust model. And with the continuing operation of the system (increase with the number of polling), this advantage is more apparent. Secondly, with the increase of task failure ratios, the increases of social benefit in system from trust model with social relationship to common trust model are more and more.

The two sets of experimental results prove that the advantage of introduction of social model in the AgentTMS in the role of simulation platform is very clear. The social relation of trust model should be better than the model without the introduction of social relations.

Ⅴ. Conclusion

MAS is considered as a system which is simulated the human beings with the computer. In order to improve collaboration and distribution efficiency, the introduction of social relations in the MAS to study the trust model. From the aforementioned experiment results, we can draw the conclusion that the Trust Model based on MAS Social Relationship —AgentTMS is essential for Multi-Agent System to bring the great benefit. The social relationships are suitable for large Multi-Agent System and suitable to be quantitative for the relationship which is produced by the natural relations and in cooperation process. And they provide the basis for MAS trust model. Formulate unified standards of resource allocation, and Agents' coordinating. With the whole MAS system general completing efficiency and the principle of service system for the entire individual Agent's need as aim, it achieves the whole system efficient and coordinated development.

Acknowledgment

The work is supported by the National Key Basic Research and Development Program of China (973 Program, No.2011CB302306), project supported by national natural science foundation of china (No. 41071248).

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