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MODELLING AND SIMULATION OF TEAM EFFECTIVENESS EMERGED FROM MEMBER-TASK INTERACTION

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ABSTRACT

A team's task process consists of allocation, processing and evaluation of a series of tasks. Team effectiveness emerges from interactions among team members. The interactions between the task process and members occur when team allocates and processes tasks. To address the effect of the interaction on team effectiveness, Multi-agent based modelling and simulation is utilized to develop a multi-agent model of team's task process, in which we put forward member relation degree and member-task matching degree to describe the social relations existing in a team and how members' competence match with tasks' demands respectively. We implement the model by Repast J and conduct experiments to validate the model using face validation technique in an actual Chinese team. The implication of the model to the team is discussed and some suggestions are offered. The conclusion is given at last.

1 INTRODUCTION

Working in forms of teams has been proved to be an effective and flexible way in practice (Bursic 1992). Coexisting with the great success of team, tremendous literatures relating to team behavior have emerged in recent years (Rousseau et al. 2006). From the perspective of Complex System teams are dynamic, emergent, and adaptive entities embedded in a multilevel (individual, team, organization) system (Arrow, McGrath,and Berdahl et al. 2000), and also complex dynamic systems that exist in a context, develop as members interact over time, evolve, and adapt as situational demands unfold (Kozlowski 2000). Therefore, whether they can be aligned with environmentally driven task demands decides whether they are effective and team effectiveness (i.e., performance evaluated by others, member satisfaction, viability) is an emergent result that unfolds across levels (individual, team) and over time (Kozlowski and Ilgen 2006) and is affected by many factors such as individual differences (Kozlowski and Klein 2000) and task complexity and interdependence (Weingart 1992). On the other hand, task process is closely connected with teamwork, and task allocation is a basic problem in distributed organizational problem solving (Sikora and Shaw 1996). Smith proposed Contract Net Protocol (CNP) as the protocol for task allocation to select the most suitable individual for a task by bidding (Smith 1980). Masahiro et al.'s work investigated a team-scaled organizational model on task allocation problem and analyzed that the use of which one of task allocation styles including CNP, Knowledge and By-itself could get the minimized communication cost (Masahiro et al. 1997).

Previous studies about team effectiveness or task process only focused on individuals' behavior in team or task process in teamwork while the combined exploration of them from a complex system perspective is insufficient. We can view a team as a system consisting of members and tasks and it is full of interactions of 1) members with tasks, 2) a member with another one, and 3) task with another one. For examples: 1) members can learn from experience during their working on tasks, as a result of which their competences are enhanced and processing time on tasks are shortened (Shafer, Nembhard, and Uzumeri 2001) and different types of tasks have different effect on members (Hu and Zhang 2006); 2) a team is also a work group of different individuals and the social interactions of team members greatly affect team performance (Mangel 1995); 3) Task interdependence refers to the extent to which team members' performance of sub-tasks requires cooperation by other members through timely or synchronized performance of inter-related sub-tasks (Campion, Medsker and Higgs. 1993) and it represents one of defining features of a team in some form (Campion, Papper, and Medsker 1996; Cohen and Bailey 1997). In addition, Chinese traditional managerial cultures have so many characteristics different from western ones, such as more emphasis laid on interpersonal relations, more privileges of mangers given on decision-making, etc. All those have effect on teams' task process and bring uncertain changes

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on teams (Hu and Zhang 2006). It will be interesting to explore the dynamic of team effectiveness in China from the perspective of interactions of team members and interactions of members with tasks.

Our approach in this paper is Multi-agent Simulation (MAS), which is a common tool used by researchers to model and simulate team behavior (Fan and Yen 2004; Hideyuki and Fusashi 2005; Robert and Marco 2005). Agents has been identified as entities which have goals, behavior and knowledge and run by themselves in a certain environment with certain properties such as autonomy, social ability, reactivity, proactivity (Wooldridge and Jennings 1995). Agent-based models (ABM) are commonly used in social sciences to represent individual actors (or groups) in a dynamic adaptive system and the social system may be a marketplace, an organization, or any type of system that acts as a collective of individuals (Garcia 2005). Researchers have been growing interest in using intelligent agents to model and simulate human teamwork behaviors (Fan and Yen 2004). Multi-agent system is a self-organized system of a few autonomic agents obeying rules of coordination. It can solve complicated problems difficult for a single agent through task decomposition and allocation and agents' coordination (Wooldridge 2002). MAS can be implemented on the platforms such as Swarm, Repast, Ascape and so on. Among the platforms Repast is adopted frequently for its advantages such as easiness for learning and good expandability. Such versions of Repast as Repast J, Repast.Net and Repast Py can be run respectively in Java, Microsoft .NET and Python (North, Collier, and Vos. 2006).

Our purpose of this paper is to explore the interaction of members and task in teamwork in a certain environment such as Chinese organizations and address interactive connections of one member and another, members and their tasks, and one task and another. In the remainder of this paper, we describe team's task process in Section 2, develop a MAS model in Section 2, implement it to a program by Repast J in Section 4 and make experiments on an actual team with the program to validate the model in Section 5, and discuss implication of the model in Section 6. Section 7 is the conclusion.

2 TEAM'S TASK PROCESS

Before modelling, we should first describe what a team's task process is. The process consists of the arrival, allocation, processing and evaluation of a series of tasks as following steps (Masahiro et al. 1997).

1. A task arrives at team from outside and is received by a manager selected by team.
2. The manager selects one of his subordinates to be the worker processing the task.
3. The worker works on the task.
4. The worker will report the result to manager as soon as he/she completes the task.
5. The team evaluates task performance and decides to reward or punish the worker and manager according to final performance of the task.
6. Next task arrives and step 1- step 5 are repeated in turn. Thus, tasks are allocated, processed and evaluated within the team repeatedly until all of them are completed.

It is assumed in this paper that there is only one manager and one worker in every cycle of task allocation and evaluation, and the manager is only responsible for allocating and evaluating the task and the worker is only for processing the task. Therefore, 2 selections will occur in every cycle, one from the team members is selected as the manager, and then he/she select one of the other members to be the worker. In team's task process members are capable of communicating with each other by sending and receiving message. We assume that a member is able to send limitless pieces of message but can only receive one piece each time.

3 THE MODEL

3.1 Variables

To describe team members' characteristics each member has been given such attributes as technical or social competence, learning ability and rewarding records and the corresponding variables are: PW_i denotes member i's competence of completing a task by technical skills and its values from 0 to 1 mean the competence being from weak to strong; PS_i denotes member i's competence of completing a task by social skills and its values from 0 to 1 mean the competence being from weak to strong; PL_i denotes member i's ability of learning when processing a task resulting in improvement of his technical or social competence and its values from 0 to 1 mean the ability being from weak to strong; R_i denotes member i's reward records accumulated through task evaluations including the manager's managerial record and worker's working record and their values from 0 to 1 mean the member being rewarded for more times.

Attributes of tasks such as demands of them on technical competence and social competence, difficulty influence and team's planning time are also given to each task in the same way and the corresponding variables are: TW_j denotes the demand of task j on technical competence of the worker and its values form 0 to 1 means the demand being from little to great; TS_j denotes the demand of task j on social competence of the worker and its values form 0 to 1 means the demand being from little to great; TD_j denotes the influence of the difficulty of task j on task

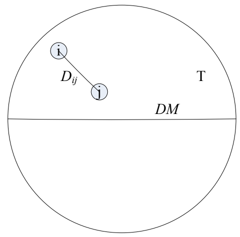


Figure 1: Member relation degree

processing time of the worker and its values form 0 to 1 means the influence being from little to great; TP_j denotes team's planning time of the task j and its positive and bigger values mean longer team's planning time on the task; TC_j denotes the time cost spent on task j' by the worker and its positive and bigger values means higher cost, where TC_j is divided into 3 parts including task allocation cost, task process cost and task evaluation cost according to different task allocation styles detailed in later content.

To describe social relations among members, member relation degree is proposed here referring to in what degree relations of members are. As shown in Figure 1, the bigger circle T represents a team and its round side points out the team's border, two smaller circles i and j represents two members i and j of the team and the movements of circle i and j constrained in the circle T mean member i and j's actions within the team they belong to. (x_i, y_i) and (x_j, y_j) are ordinates of the center of circle i and j respectively and, the distance between two centers be D_{ij}, and diameter of circle T be DM. Then RD_{ij} can be calculated as Equation (1).

$$RD_{ij} = \frac{DM - D_{ij}}{DM} \tag{1}$$

Where, D_{ij} equals the square root of $(x_i - x_j)^2 + (y_i - y_j)^2$. Such descriptions of members' social relations with the help of geometric circles are preparations made for displaying the interactions of members in the program (see Section 4).

To describe how well members' competences match with the demands of tasks, member-task match degree (MD) is presented here referring to the degree of members' technical or social competences matching with the demands of tasks on corresponding competence.

$$MD_{ij} = \frac{PW_i}{TW_j} * \frac{PS_i}{TS_j} \tag{2}$$

Where, MD_{ij} is MD of member i and task j, PW_i、PS_i are repectively member i's technical and social competences, TW_j、TS_j are respectively task's demands on technical and social competence of the worker.

Continued with the task cost of a task, it is the sum of 3 parts of costs and calculated as Equation (3).

$$TC_j = w_1 * TAC_j + w_2 * TPC_j + w_3 * TEC_j \tag{3}$$

Where, TC_j is the total task cost of task j; TAC_j is the cost of task allocation; TPC_j is the cost of task processing; TEC_j is the cost of task evaluation; w_1, w_2, w_3 is respectively the weight of TAC_j, TPC_j, TEC_j.

For the aspect of task allocation cost, there are different styles for task allocation including CNP, RD and hybrid ones and they all produce time costs. The costs produced on all these styles are calculated as Table 1.

Table 1: Time costs of task allocation style

Task allocation style	TAC_j
CNP	$(2m-1)T$
RD	0
RD-CNP	$(2ms+1)T$
CNP-RD	$(2m+ms-1)T$

Where, TAC_j is task allocation cost of task j; m is the total number of members; T is the time cost of sending a piece of message, ms is the number of members selected by the manager according to the first style of the hybrid one. Style of CNP means that the task manager communicates with other members and tells them the information about the task, the other members send bids to the manager and the manager inform them who is selected as the worker all by means of sending or receiving message which brings time costs. Style of RD means that the manager selects the one with the biggest RD to him among other members as the worker, and the manager allocate the task to the member with the closest relationship with him. RD-CNP means that the manager first select some candidates from members on RD style and then selects one from candidates to be the worker on CNP style. CNP-RD means that the manager select some candidates from members based on CNP and then select one to be the worker.

For the aspect of task processing cost, it is calculated as Equation (4).

$$TPC_j = \frac{TP_j * (1 - TD_j)}{MD_{ij}} \tag{4}$$

Where, TPC_j is task processing cost of task j; MD_{ij} is MD of member i and task j; TP_j is team's planning time of task j; TD_{ij} is the influence of task difficulty on processing time of task j.

For the aspect of task evaluation cost, the worker reports to the manager when completing the task, the team evaluates the performance of the worker, and the results are published by the manager to other members. During the course, communication between the manager and other members will bring time cost which is task evaluation cost calculated as Equation (5).

$$TEC_j = mT \tag{5}$$

Where, TPC_j is task processing cost of task j; m is the total number of members; T is the time cost of sending a piece of message.

3.2 Rules

First, Member Interaction Rules are given here including member-member interaction rules, manger-worker interaction rules, manager selection rules and worker selection rules.

- Member-member Interaction Rules (MMIR). As shown in Figure 1, movements of the smaller circles *i* and *j* in the bigger circle means that actions of member *i* and *j* within a team. During a task being processed, two smaller circles can move in all directions. As a result of the movements, the distance between them will get shorter or longer. We make use of the changes of the distance to represent the changes of relation degree between two members.
- Manager-worker Interaction Rule (MWIR). The manger and worker will be rewarded or punished for their performance in task evaluation (See Section 2). The reward or punishment will have negative or positive effect on the relation of the manager and worker and RD of them will be enhanced or reduced as a consequence. As shown in Figure 1, if circle *i* and *j* denote manager *i* and worker *j* respectively, the influence of punishment or reward on relation of manager *i* and worker *j* will makes the two circles move along the line of their center and their distance will change. We assume that the distance of each circle's movement is still d. Then new RD of manager *i* and worker *j* can be calculated according to Equation (1).
- Manager-selection Rules (MSR). A manager will be selected from members to allocate new task before task allocation (See Section 2). The selection depends on probability calculated based on members' managerial record and his RD with other members as Equation (6), (7) and (8).

$$ARD_i = \frac{1}{m-1}\sum_{1\le j\le m, j\ne i} RD_{ij} \tag{6}$$

$$Z_i = w_4 * \frac{MR_i}{\sum MR_i} + w_5 * \frac{ARD_i}{\sum ARD_i} \tag{7}$$

$$MP_i = \frac{Z_i}{\sum_{i=1}^{m} Z_i} \tag{8}$$

Where, ARD_i is the average RD of member *i* and all other members, R_i is the managerial record of member *i*, Z_i is sum of weighed MR_i and ARD_i, w_4, w_5 are the weights of MR_i and ARD_i respectively, MP_i is the probability of member *i* selected as manager.

- Worker Selection Rules (WSR). When a task arrives, the manager will allocate the task to one member (See Section 2). There have been 4 styles of task allocation available for the manager. Another style is added here, in which the manger chooses one of the 4 styles on probabilities calculated as Equation (9) based on the manager's managerial records.

$$WP_i = \frac{MR_i}{\sum_{i=1}^{4} MR_i} \tag{9}$$

Where, WP_i is the probability of style *i* to be used to choose the worker by the manager . MR_i is the managerial record for style *i*.

Secondly, Serial Task Rules (STR) are the rules given that the task arrives at the team in turn and a task won't arrive until last task is completed. The arrival, processing and allocation and evaluation of parallel tasks are not considered here.

Thirdly, Member-task Interaction Rules (MTIR) are the rules of members interacting with their tasks including worker learning rules and manager-worker reward rules.

- Worker Learning Rules (WLR). The worker is able to learn experience during working on a certain task. As a consequence, his competence changes in the degree decided by his learning ability, the new values of competence are calculated as Equation (10) and (11).

$$PW_i' = (1-PL_i) * PW_i + PL_i * TW_j \tag{10}$$

$$PS_i' = (1-PL_i) * PS_i + PL_i * TS_j \tag{11}$$

Where, PS'_i and PS_i are respectively the old and new values of worker *i*'s social ability. PW'_i, PW_i are respectively the old and new values of worker i's technical competence. TS_i and TW_i are respectively the demand of task *j* on worker's social and technical competence. PL_i is worker *i*'s learning ability.

- Manager-worker Reward Rules (MWRR). The rules are set for the team to reward or punish the manager or worker if the time spent on the task is shorter or longer than team's planning time. All the rewards or punishment will be recorded accumulatively in the members' reward records. The variation of the record is calculated as Equation (12) and (13)

$$\Delta R_i = \frac{TP_j - TPC_j}{TPC_j} \tag{12}$$

$$R_i' = R_i + \Delta R_i \tag{13}$$

Where, ΔR_i, R_i and R'_i are respectively the incremental, old and new values of member *i* (the manager or the worker)'s reward record; TP_j is team's planning time of task *j*; TPC_j is the task processing cost of task *j* by the worker.

3.3 Agents

Based on variables and rules described above, we define the agents in the model. They are task agents and human agents representing tasks and team member respectively and human agents are classified into 3 types including the ones representing the manager, worker and other members. The agents representing different entities have different goals and act differently for their goals and they have member or task attributes. For an example, the task agents with task attributes arrive according to TSR; the manger agents with member attributes select worker agent for a given task agent, evaluate the task and are rewarded or punished according to MMR, MWR, MSR, WRL, MWRR; the worker agents with member attributes working on the task, report to manager when completing it, and is rewarded or punished according to MWR, WLR, MWRR; the other member agents receive task information, bid for being worker and receive the result of the evaluation according to MMR, MSR.

According to agents of the model defined above, the model is developed with the interactions involved in shown in Figure 2.

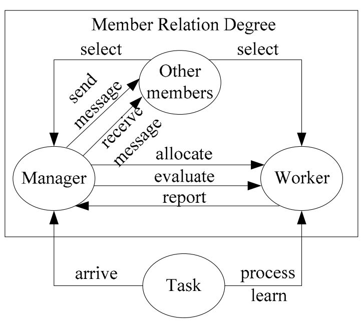


Figure 2: Interactions of members and tasks in the model

3.4 Evaluation criteria for outputs

To explore the gaps of team effectiveness in different scenarios three evaluation criteria are given as follows:

- Cost criterion. In such a criterion, the assessment of team effectiveness depends on the average of task cost. The team with the smallest average will be thought as the most effective team. Let TC_{ij} be the total task cost of task *j* in scenario i, ATC_i be the average task cost of task*s* in scenario i, the number of tasks be *n*, and then ATC_i can be calculated as Equation (14).

$$ATC_i = \frac{1}{n}\sum_{j=1}^{n} TC_{ij} \qquad (14)$$

- RD criterion. In such a criterion, the assessment of team effectiveness depends on the average of all team members' mutual relation degree. The highest team effectiveness will be believed existing in the scenario in which the team has biggest average RD of members. Let ARD_{ij} be the average relation degree of member *i* in scenario *j*, $SARD_i$ be the average relation degree of all members, the number of members be m, and then $SARD_i$ can be calculated as Equation (15).

$$SARD_i = \frac{1}{m}\sum_{j=1}^{m} ARD_{ij} \qquad (15)$$

- Integrated criterion. Combining cost criterion with RD criterion, integrated criterion is set to assess team effectiveness by means of Fuzzy Comprehensive Assessment (Tao and Yang 1998). The fuzzy value calculated through FCA is used for the assessment of team effectiveness here. The team with bigger FCA values will be thought as more high in team effectiveness. Let CV_{ij} be the FCA value of scenario i, and then it can be calculated as follows..

$$CV_i = w_6 * \frac{Max(ATC_i) - ATC_i}{Max(ATC_i) - Min(ATC_i)} + w_7 * \frac{ARD_i - Min(ATC_i)}{Max(ATC_i) - Min(ATC_i)} \qquad (16)$$

Where, w_6, w_7 are the weights of fuzzy assessment value of average of Task cost and RD in FCA value respectively.

4 IMPLEMENTATION

We employ Java and Repast J 3.0 in Eclipse 3.1 to code the multi-agent model developed above into a simulation program. The user interface of the program is shown as Figure 3. In the program, the parameters initiated before the running of simulation are including total number of team members *m* and tasks *n*, fluctuating rate *d*, six weight variables w_1, w_2, w_3, w_4, w_5 , w_6 and w_7, number of firstly selected candidates, *TP* of each task, the cost of sending a piece of message, the distribution function of members' competences, every member's managerial and working records, etc. the attributes of tasks like task cost and their

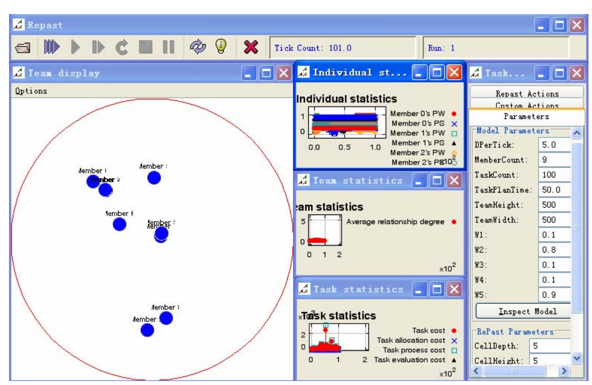


Figure 3: The user interface of Repast program

demands on the worker can be different from each other or the same as each other.

5 VALIDATION

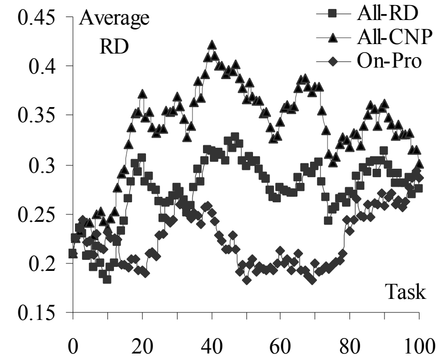
There are many validation techniques including face validity, parameter variability - sensitivity analysis and so on (Sargent 2004). For the validation of the model we will employ face validity, which is employed to see if the input, output and their relations are reasonable compared to the common knowledge of team management in situations of real systems such as an actual team.

The actual project team selected for validation is from a Chinese sub-government organization, which is part of the government but funded by both of the government's foundation and its own profit. We explore members' behavior and member-task interaction of the team with our simulation program as a validation of our model and a way to finding suggestions for decision-makers through simulations.

The team consists of 15 people, of which many characteristics are found. To simulation such a team we deal with it with knowledge descriptions of the model. Therefore, the initial settings of the simulation program are as follows.

M is 9 and n is 100. The members' competences are including head members' competences and subordinate members' competence. The distributions of the head members' technical and social competences are U(0, 0.5) and U(0.5,1), while the distributions of the head members' technical and social competence are U(0.5, 1) and U (0, 0.5). The distribution of their learning ability are U(0, 1). The team is represented by a circle with its diameter being 500. The fluctuating range of member relation degree is 5. The initial values of every member's reward record (including managerial record and working record) are 0. 3 members will be firstly selected in hybrid allocation style. The demands of task on the worker's competence are changing dynamically. It is assumed that the distribution of the demand of a task on a worker's technical competence is U(0,0.5) and the distribution of the demand of a task on a worker's social competence is U (0.5, 1) for first 50 task while one of distributions is U(0.5, 1) and the other is U (0, 0.5). w_1 is 0.1, w_2 is 0.8, w_3 is 0.1, w_4 is 0.1 and w_5 is 0.9. Team's planning time varies from 100 to 20 linearly. The initial status of members in team diagram is that member 1, 2 and 3 are head members and the others are subordinate members who distribute around their head and that there are certain distances among different small groups.

We need to explore not only the case that the selection of the worker is fully based on member relation degree to make it closer to reality, but also the one that the selection of the worker is fully based on the contract net protocol or



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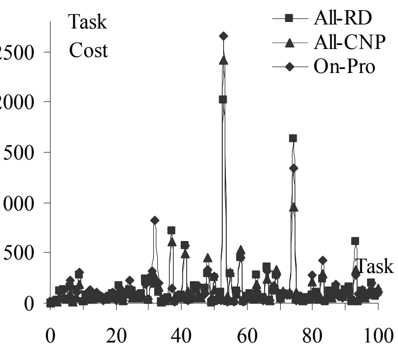
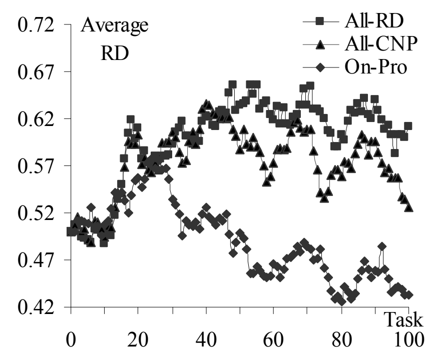


b

Figure 4: Results in case a using 3 rules



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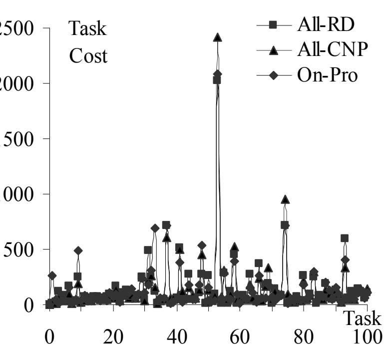

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Figure 5: Results in case b using 3 rules

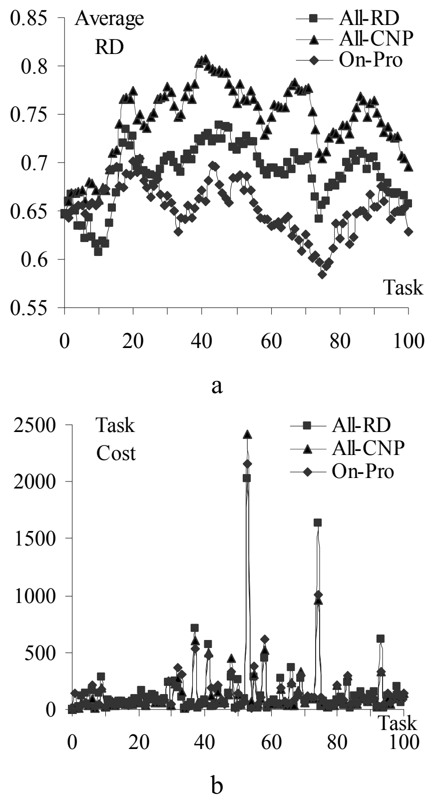

Figure 6: Results in case c using 3 rules

Table 2: Simulation Results of cases using 3 rules on evaluation criteria

Case	Initial Average RD		Worker Selection Rule	Criterion		
				Cost criterion	RD criterion	Hybrid criterion
a	low level	0.209	All-RD	147.436	0.274	0.388
			All-CNP	139.959	0.337	1
			On-Pro	151.363	0.225	0
b	medium level	0.5	All-RD	139.751	0.598	1
			All-CNP	139.959	0.574	0.632
			On-Pro	140.155	0.491	0
c	high level	0.646	All-RD	147.436	0.689	0.196
			All-CNP	139.959	0.744	1
			On-Pro	143.329	0.653	0.275

based on the probability decided by member's working record for comparison with the former case. The rules of worker selection listed above can be abbreviated as 1) all-RD rule, 2) all-CNP rule and 3) On-Pro rule. We assume that different average of initial member relation degree will result in gaps in simulation results. So we simulate 3 cases:

- Case a: the initial average RD is in a low level;
- Case b: the initial average RD is in a medium level;
- Case c: the initial average RD is in a high level.

The simulations of 3 cases with 3 rules are run and the statistical graphs of simulation results are shown in Figure 4-Figure 6. Data in cases using each rule and the results evaluated are listed in Table 2 where w_6 and w_7 are both 0.5.

As described before, the temporary manager of the team allocates the task based on other member's RD with him and the worker selection rule is all-RD. We observed that there is little connection of members in and out of a department. Therefore, we thought that case a using rule 1 is the one nearest to the fact. The line with squares in Figure 4a shows that average RD waves during task process and the initial value of average RD is 0.209, the highest one is 0.328, the lowest one is 0.183 and the average one is 0.274. The result indicates that if the average initial RD is low the average RD in the whole task process will also be low and there is no significant difference among the average RD values during tasks. The line with squares in Figure 4b also shows that task cost changes dramatically and abnormal values occur sometimes. The results of RD and task cost are both validated in the actual team by our survey, which indicates that informal small groups exist in the whole task process and there are still big gaps between them, and that a few tasks will be postponed so much that they were cancelled. Furthermore, we consider case b using rule 1 (see Figure 5a, Figure 5b and Table 2) and case c using rule 1 (see Figure 6a, Figure 6b and Table 2). We found that the average RD waves in a little degree in both cases with the initial and average RD being 0.598 and 0.5 in case b and 0.689 and 0.646 in case c. The results have agreement with the one in case c using rule 1. There exist abnormal values of task cost in two cases, too. The big values of task cost like 2021.164 mean that the task takes so long time to complete that it is usually cancelled. It agrees with the fact. Therefore, our model is validated in case b and c both using rule 1 through the comparison of actual case with the simulation results.

6 DISCUSSION

The validation of our model in prior context makes it possible to use the model in analysis of some problems in management of the actual team detailed in Section 5. To explore how different rules in different cases influence team effectiveness, we simulate the scenarios of 3 cases using other 2 rules, and the results are statistically graphed in Figure 4, Figure 5 and Figure 6. Figure 4 with data listed in Table 2. They exhibit the difference of the scenarios well. About average RD, Figure 4 shows that rule 2 is the best of the three that were tested in that it promotes average RD in the maximum degree, rule 1 is the suboptimal one, and rule 3 is the worst in case a and c. Figure 5 shows that rule 1 is better than rule 2, and rule 3 is still the worst in case b. However, Figure 4, Figure 5, Figure 6 and Table 2 can not make clear the difference of task cost among cases. Table 2 shows that rule 2 is the best in case a while rule 1 is the best in case b if evaluated on cost criterion and that evaluation on integrated criterion is the same as the one on cost criterion. Hence we concluded as follows:

- If team effectiveness is evaluated on RD criterion, All-CNP should be used in the whole task process to improve team effectiveness if the relations of members are in a lower or higher level in the beginning of a project. All-RD is also able to be used for better team effectiveness only if the relations of members are in a medium level. But whether the initial member relations are in a low or high level, All-Pro is not favorable for team effectiveness.
- If team effectiveness is evaluated on cost criterion, All-RD will help for reduction of task cost in task process if the relations of members are in a lower or higher level in the beginning of a project. All-RD will be prior for better team effectiveness if the relations of members are in a medium level.
- If team effectiveness is evaluated on integrated criterion with the weight of task cost and RD both being 0.5, the conclusion is the same as 2).

The application indicates the implication of the model. However, there are still limitations in the model in this paper. For an instance, tasks are set to arrive at the team one by one serially and the arriving time of next task is set as the departing time of last task. Obviously it is not consistent with the arrival of tasks in real world because when one or more tasks are still being processed another one or more tasks may arrive. For consistence of the model with real system, it should be improved and in a result the model's output including task cost and members' relation degree will change. The implementation of the model should also be made in the way of parallel simulation programming. Thus, the problems should be examined in further study. In addition, the members' learning ability are important factors affecting the output of the model. What will happen if learning ability is set to be various dynamically is also interesting for further studies.

7 CONCLUSION

We have developed a multi-agent model in this paper to describe team member-task interaction based on the theory of team behavior, contract net protocol and the approach of multi-agent modelling and simulation. We addresses some characteristics of team, individuals and tasks into account and defines them as different variables in the model and design and run simulation on an actual Chinese team to validate the model, and then we discuss the application of the model to the team and give some suggestions for improvements of management of the team.

The model and simulation of team effectiveness from the perspective of member-task interaction are useful for researches on dynamics of interactions of tasks and members in a team to address how the interactions affect team effectiveness. Because the task process made up of by task allocation, processing and evaluation is the main work of a team such as official documenting affairs in governments, product task allocations and parts processing in the machine in enterprises. Therefore, the model has a bright future for further studies.

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