Research on Mental Coefficient of a Multi-Agent Negotiation Model

Yu-Mei Jian and Ming Chen

Abstract In Multi-Agent system, negotiations model was commonly used by contract net. A multi-agent negotiation model based on the acquaintance coalition and the mental coefficient contract net protocol are presented to improve the efficiency of negotiation. The structure of the multi-agent negotiation model is given to support the acquaintance coalition contract net protocol. The trust degree parameter, familiar degree, reliability degree, busy degree of mental state, and the update rules are introduced. Finally, through an example and analysis of a Robot soccer system which uses the model, improvements of the negotiation efficiency and negotiation communication traffic is proven.

Keywords Contract net · Acquaintance coalition · Mental coefficient · Multi-agent

1 Introduction

In Multi-Agent system, negotiation plays a very important role in solving the conflict of goals and resources. Many thinning and complement were made in the actual apply process. Sand Holm drew boundary cost count into the process of bidding and awarding of contract net [1, 2], Chen used bid threshold value [3] to restrict calculate and communication cost during the negotiation; Fischer etc. [4] optimized task allocation by drawing provisional trust refuse, and mocked trading into contract net; Collins [5] mixed arbitration mechanism into the negotiation process to prevent fraudulent conduct in tendering process; Lee [6] drew acceptance term into contract net to adapt task environmental changes; Conroy [7]

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introduced the multi-step negotiation into contract net, repeatedly negotiations were allowed during bidding or to win the bidding; the literature [8] mentions a Multi-Agent Cooperation Model based on Improved Dynamic Contract Net Protocol (MACMIDCNP). To bid by making the alliance as a unit in MACMIDCNP, to calculate the optimal alliance which can finish the task by using mingle inheritance ant algorithm, and to choose the alliance as contractor directly base on reliability. Thus it could greatly reduce communication cost and save systematic run time by lessening the communication boundary to alliance itself inside, and also it enhances the whole performance of the system. The literature [9] mentions dynamic contract net with fault-tolerant ability, the contractor had the strategy of task option, the recognition of fault contractor, the task recovery and secondary scheduling and the rules for reliability updating, draw trust, steady, cooperation frequent, and positive level in the process of bidding and awarding, at the same time, the literature [9] proposes a algorithm-multi-rank top-n random select algorithm, which considered cooperator to complete the task's history situation and abilities' change. The literature [10] adds mental coefficient based on acquaintance alliance, it packed the task as a bid book, and published bid book to commonality blackboard, when there were no bid agents for a given task.

The multi-agent cooperation model which based mental state mentioned in this paper, introducing the strategy of acquaintance alliance and mental state into typical contract net comparing with DCNP, MACMMS newly increased reliability, busyness, intimate, satisfaction, initiative, etc. This paper presents the classification function and the rules for updating reliability, busyness. On the basis of ensuring the quality of negotiation quality, MACMMS effectively advance the efficiency of negotiation and prove the effectiveness by researching the test of robot football match [11] and its result data.

2 Multi-Agent Cooperation Model

2.1 Negotiation Process

In MACMMS, other agents bid to become a negotiation agent after management agent sends out a task. Negotiation process defines as a five-element group: <G, S, A, Time, Protocol>.

- G: All agents who want negotiation are divided into three types: management agent, negotiation agent, consultant agent.
- S: All tasks.
- A: Negotiation process value. Acceptance means consultant agent accepts to execute the task, refusal means refuse negotiation, rejection means the consultant agent rejects to execute consultant task. Both rejection and refusal may lead to the restart of negotiation.

- Time: System clock arranges by order natural world. It limits negotiation time and must finish if negotiation time exceeds limit time.
- Protocol: Negotiation treaty (Fig. 1)

Step 1 Before negotiation, management agent receives a task T_j, resolves the task to $T_j = \{t_1, t_2, \ldots t_j\}$ and classifies the acquaintance to acquaintances gather, general acquaintances gather, and strangeness gather by mental coefficient of each task.

Step 2 Management agent sends bid information to every task's acquaintances gather and general acquaintances gather.

Step 3 Negotiation agents solve bid wish value Price (t_j) of each task by bid information and negotiation algorithm.

Step 4 After limit time, management agent decides the last consultant agent among negotiation agents' bid condition by win the bidding decision function.

Step 5 Negotiation agents change their initial offer. If the winner (consultant agent) wills to execute task, consultant agent sends affirm to management agent. Management agent turns to step 9 if it did not receive confirm information.

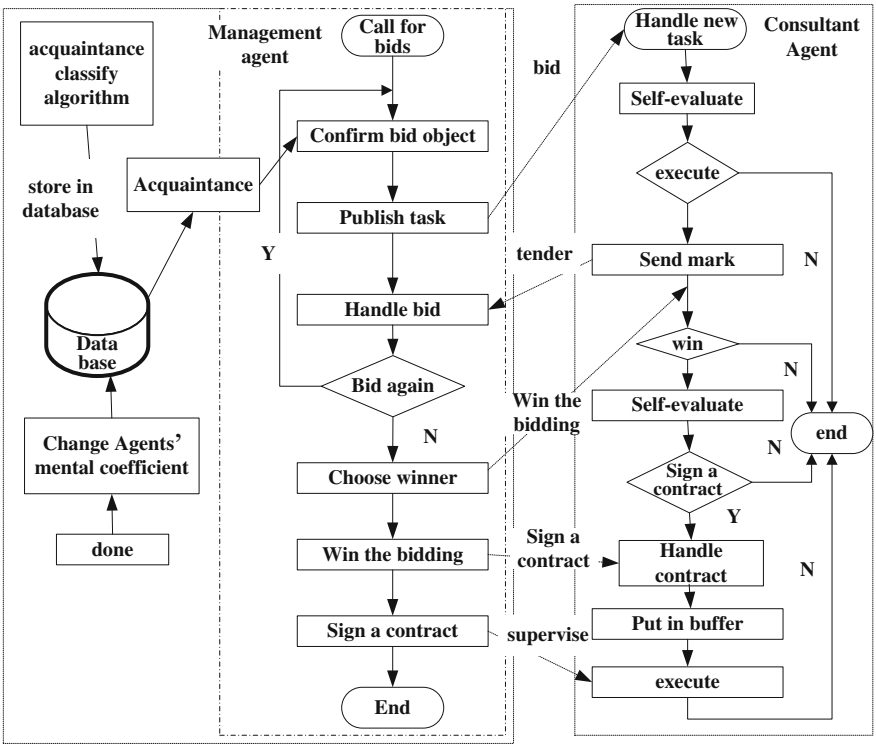

Fig. 1 Negotiation processes of a mental coefficient contract net

Step 6 If management agent receives a confirm information in the limit time, it sends task to consultant agent and supervises consultant agent finish task, or if consultant agent rejects or refuses, algorithm should turn to Step 9 and renegotiate.
Step 7 Consultant agents execute task after it receives it and updates its own self-confidence, reliability, and busy factor.
Step 8 Send information to management agent when task does not finish on time, and updates consultant agent's self-confidence, reliability, and busy factor. Then turn to step 9.
Step 9 One wheel negotiation is over.
Step 10 Management agent decides to run a new bid, turn to step 2.
Step 11 Task negotiation is over.

2.2 Definition and Update Agents' Mental Coefficient

Mental coefficient is the standard of each agent action. The following mental coefficient was defined in the improved contract net model:

1. Self-confidence

It is the Self-confidence of each agent finish task. The References [12, 13] defined self-confidence too.

Definition 1 Self-confidence of Agent_m finish task t_j is described as follows:

$$C(\text{Agent}_m,\ t_j), C \in [0,\ 1]. \tag{1}$$

Self-confidence is an estimate to agent self. When C (Agent_m, t_j) = 0, Agent_m do not have the ability to finish task t_j; when C (Agent_m, t_j) = 1, Agent_m can finish the task by 100 %. Agents' self-confidence increases when it successfully completes a task; conversely, it reduces agents' self-confidence when it does not successfully complete a task. The update function of Self-confidence is defined as follows:

$$C(\text{Agent}_m,\ t_j) = \begin{cases} C'(\text{Agent}_m,\ t_j) + I_{t_j}^m \cdot e, & 1 \geq I_{t_j}^m > 0 \\ C'(\text{Agent}_m,\ t_j) - r, & I_{t_j}^m = 0 \end{cases}, \quad C \in [0, 1] \tag{2}$$

In Eq. 2, $I_{t_j}^m$ expresses the finishing rate when Agent_m fulfills task t_j. when $I_{t_j}^m > 0$, self-confidence of Agent_m could increase $I_{tj}^m \cdot e \quad e \in R$. When $I_{t_j}^m = 0$, self-confidence of Agent_m could drop r, $r \in [0, 1]$, e and r both the influence factor of self-confidence.

2 Busy

Definition 2 busy after Agent_m accept task t_j is described as follows:

$$B(\text{Agent}_m) = \frac{n_{t_j}}{n_{\max}}, \quad B \in [0, 1] \tag{3}$$

Busy is used to present agents' busy state. In the definition, n_{tj} means the number of Agent_m has now (include task t_j); $n_{\max}$ means can handle the maximum of Agent_m in the same time. When B (Agent_m) = 1, it means Agent_m has already achieved task saturation state, Agent_mcannot accept any task. If B (Agent_m) $\neq$ 1, n_{t_j} needs to add 1 and update B (Agent_m) to adjust consultant agents' busy when consultant agent adds one cooperation task every time.

3 Reliability

Definition 3 Agent_m considers the self-confidence of Agent_m successfully fulfilling task t_j is described as reliability, the definition is as follows:

$$T_{\text{Agent}_i}(\text{Agent}_m,\ t_j) = \frac{\sum_{w=1}^{N_{t_j}{}^m} I_{t_j}{}^m(w)}{N_{t_j}^m}, \quad T \in [0, 1] \tag{4}$$

Reliability means trust degree between Agent_i to another agent, which is reflected in the trust relationship between agents, $I_{t_j}^m(w)$ presents finishing rate of Agent_m successfully finishes Agent_i's wth task t_j; N_{tj}^m is the number of Agent_i relegate tasks t_j to Agent_m. When $T = 1$, Agent_i consider Agent_m can finish task t_j by 100 %, otherwise, Agent_i think Agent_m do not have the ability to finish task t_j.

4 Intimate

Intimate is used to measure the familiar degree of cooperative relationship between agents. In the reference [13] appeared the definition of intimate.

Definition 4 Intimate is considered as the frequent degree of Agent_i and Agent_m working together to deal with task; the definition is as follows:

$$R(\text{Agent}_i,\ t_j,\ \text{Agent}_m) = \frac{N_{tj}^m}{N_{tj}^i}, \quad R \in [0, 1] \tag{5}$$

In Eq. 5, $N_{t_j}^m$ is number of Agent_i relegating task t_j to Agent_m, $N_{t_j}^i$ means the total number of Agent_i relegate task t_j. Compared with the literature [14], this paper expansion intimate's boundary, contribute self-confidence and reliability's update.

5 Satisfaction

Satisfaction is the evaluate result of every cooperative, including the task completion quality of the solution and the time of evaluation.

Definition 5 Satisfaction is defined as Agent_m finishing the wth task t_j of Agent_i:

$$S_{\text{Agent}_i}^w(\text{Agent}_m, t_j) = kq \cdot q(\text{Agent}_m, t_j) + kt \cdot t(\text{Agent}_m, t_j) \tag{6}$$

In Eq. 6, $q(\text{Agent}_m, t_j)$ is the quality evaluation of Agent_m finish task t_j; $\text{t}(\text{Agent}_m, t_j)$ is the time evaluation value; K_q, K_t respectively, mean weight of quality evaluation, time evaluation. The total satisfactions of Agent_i consider Agent_m finish task t_j was described as follows:

$$S_{\text{Agent}i}(\text{Agent}_m,\ t_j) = \sum_{w=1}^{N_{t_j}^m} kw \cdot S_{\text{Agent}i}^w(\text{Agent}_m,\ t_j) \tag{7}$$

In Eq. 7, $N_{t_j}^m$ is number of Agent_i relegating task t_j to Agent_m, K_w means the weight of every cooperation satisfaction.

6 Initiative

Definition 6 The initiative was described as follows:

$$A(\text{Agent}_i,\ t_j,\ \text{Agent}m) = \frac{N_{t_j}^{'m}}{N_{t_j}^i}, \quad A \in [0, 1]. \tag{8}$$

Initiative is the positive degree of negotiation agent, it has nothing to do with winning the bid, $N_{t_j}^{'m}$ is number of Agent_m relegating task t_j to Agent_i, $N_{t_j}^i$ is the total number of Agent_i entrust task t_j.

2.3 Definition of Acquaintance Model and its Sort Management

Definition 7 The acquaintance of Agent_a is defined as some agents which successfully cooperate with task a_i more than a certain frequency. In the negotiating process, acquaintances set and the formation of negotiation model is called acquaintance model.

Definition 8 $E_{\text{Agent}_m} = \left(T_{\text{Agent}_m}, R_{\text{Agent}_m}, S_{\text{Agent}_m}, A_{\text{Agent}_m}\right)$ which means the overall merit of Agent history recording, embodies the task for degree, called a familiar degree.

2.3.1 The Concept of Acquaintance Coalition

The literature [15] introduces alliance, this paper defines acquaintance model as participating in cooperation all the resources of the mental state information Agent of the abstract description.

Definition 9 $F_{\text{Agent}_m} = <C, E(T, R, S, A), B>$, which means the acquaintance model is based on the mental coefficient. C is the self-confidence of Agent_m; E is Intimate; B is the busy of Agent_m.

2.3.2 Classify Acquaintance Coalition

Every agent can classify as acquaintance, general acquaintance, and strangeness.

Agent $=<$ $\text{Agent}_f >+<$ $\text{Agent}_y >+<$ $\text{Agent}_p >$, Agent_f means acquaintance, Agent_y means general acquaintance, Agent_p means strangeness.

Definition 10 The definition formula of Agent_f is described as follows:

$$\text{Agent}_f = \{\ \text{Agent}_f | C \geq C_{tj} \cap E \geq \text{eval}_{tj} \cap L(E) < \text{l}_{t_j}\}$$

Definition 11 The definition formula of Agent_y is described as follows:

$$\text{Agent}_y = \{\ \text{Agent}_y | C \geq C_{tj} \cap E < \text{eval}_{tj}) \cup (C \geq C_{tj} \cap \text{E} \geq \text{eval}_{tj} \cap L(E) > \text{l}_{tj}\}$$

Definition 12 The definition formula of Agent_p is described as follows: $\text{Agent}_p = \{\ \text{Agent}_p | C < C_{tj}\}$

In Definition 10–12, C_{t_j} is the self-confidence lower limit, eval_{tj} is the task history comprehensive evaluation lower limit, L(E) is a sort function, which express the ranking in the similar agent of E, l_{t_j} is the comprehensive evaluation ranking.

2.3.3 The Management of Acquaintance Coalition

In the initial state, acquaintance model, Agent_f, Agent_y and Agent_p both initialized to empty. Management agent chooses an agent as cooperation Agent whose self-confidence was the biggest, then updates the cooperation Agent's mental coefficient.

Definition 13 The communication record is described as Contact - F(Agent_i)= $< L_1, L_2, \ldots L_m >$. Lm is the communication information of acquaintance Agent_m, and $L_m = <$ ID, Address , C, L(E), $B >$, ID is the identifier of Agent_m, Address is the communication address, Contact - F(Agent_i) is acquaintance communication record, Contact - Y(Agent_i) is general acquaintance communication record.

2.4 Bidding and Decision Function

2.4.1 Bidding Document

Definition 14 Bidding was defined as $\text{Announce}(t_j) = \{$ Des, Ability (t_j), Bid $-deadline, Price(t_j), \ldots\}$. Des describes the particular task. Ability is the capacity gather to solve task t_j, which express as $\text{Ability}(t_j) = \{ \text{Ab}_1, \text{Ab}_2, \ldots, \text{Ab}_n\}$, Price (t_j) is the bidding price (Eq. 9); Bid-deadline is the blocking time.

$$\text{Price}(t_j) = \text{COST\_}T_j * \text{k\_}t_j * \text{s*k}, \quad \text{s, k} \in (0,\ 1] \tag{9}$$

In Eq. 9, $\text{COST\_}T_j$ is the planning overhead of task T_j; k_t_j is the weight of subtask t_j; s is the load coefficient, when $s = 1$, the system's load is empty.

2.4.2 Bidding Decision Function

Negotiation agent first checks their own self-confidence C, synthetically considering the busy degree B, the blocking time Bid-deadline of task and the actual expenses(COST) when it received task information in effective time, if $\text{COST\_}T_j > \text{Price}(t_j)$, negotiation agent do not have eligibility to bid.

The evaluation formula of Agent_m to bidding task t_j is described as Eq. 10:

$$\text{J}_{\text{Agent}_m}(t_j)=k_c * C(\text{Agent}_m,\ t_j) + k_{\text{em}} * \text{EM(Bid - deadline)} \tag{10}$$

In Eq. 10, $J_{\text{Agent}_m}(t_j)$ means the evaluation value of Agent_m to bidding task t_j; EM (Bid-deadline) is task emergency degree function; K_c is the weight of self-confidence and K_{em} is the weight of emergency degree.

The bidding document of consultant agent sends bidding document to management agent described as Eq. 11:

$$\text{Bid}(\text{Agent}_m,\ t_j)=\left\{\text{ID, Address, Ability}_{\text{Agent}_m},\ B\text{Price}_{\text{Agent}_m}(t_j),\ \ldots\right\} \tag{11}$$

In Eq. 11, $B\text{Price}_{\text{Agent}_m}(t_j)$ is bidding price, the computational formula as Eq. 12:

$$B\text{Price}_{Agent_m}(t_j) = \text{COST}\_T_j * (1 + B) \tag{12}$$

2.4.3 Win the Bidding Decision Function

When the task to the deadline of the bid, according to the received tender, management agent synthetically considering the bid price ($B\text{Price}_{\text{Agent}_m}(t_j)$) and historical records comprehensive evaluation E, select the maximum definition agent as consultant agent according to the decision function (Eq. 13).

$$\text{Sel}(\text{Agent}_m,\ t_j) = K_{BP} * B\text{Price}_{\text{Agent}_m}(t_j)+K_E * E \tag{13}$$

In Eq. 13, $\text{Sel}(\text{Agent}_m,\ t_j)$means the evaluation value of Agent_m finishing task t_j, K_{bp} is the weight of bid price and K_E is the weight of comprehensive evaluation.

3 MACMMS Algorithm

Contract net algorithm based on mental factor is shown in Fig. 2:

MACMMS Algorithm: Negotiation algorithm of contract net based on mental coefficient.

Input:

subject A = {Agent1, Agent2,…….Agent n}

Tasks T = {T1, T2,……Tn}

Every agent has its initial self-confidence, reliability, busy, intimate, satisfaction, and other related coefficient, each task also contains the minimum confidence and cost of coefficient which were required to complete task.

Output: Task record

Steps:

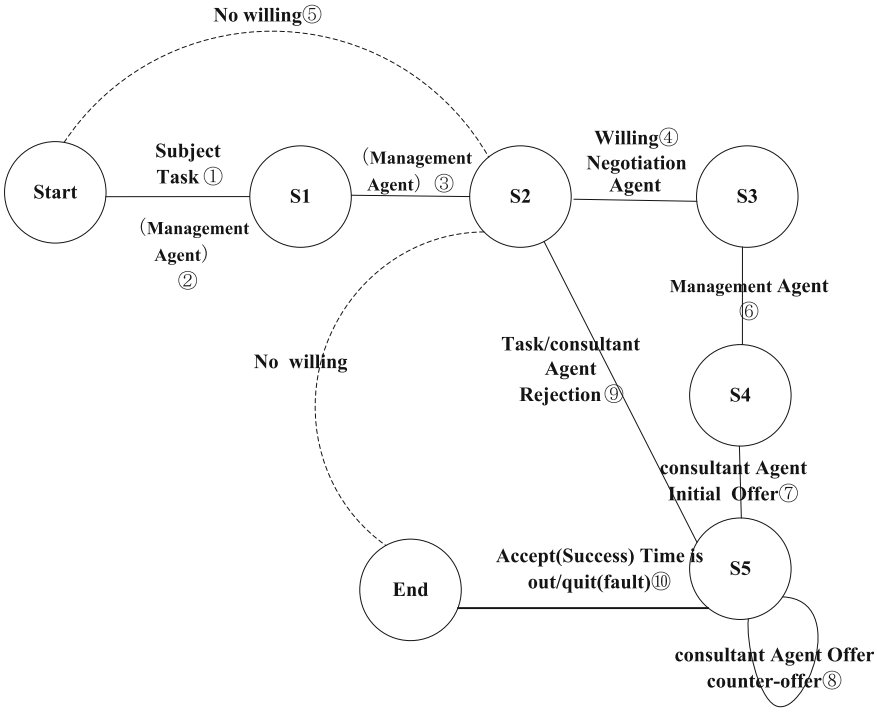

Fig. 2 Negotiation algorithm

Step 1 Find out the comprehensive evaluation value of each Agent by Definition 8, and sort the data in database.

Step 2 Management agent classifies every task into acquaintances gather; general acquaintances gather and strangeness gather according Definitions 10, 11, 12.

Step 3 For each data transmission, negotiation agent tests its bidding qualification by Eq. 9.
If negotiation agent has tender eligible, calculate out its evaluation value by Eq. 10, send bid to management agent in the form of Eq. 11, and after bidding calculate the bid price by Eq. 12.

Step 4 For data transmission task, in the bidding cases, based on the bid decision function, management agent select each task to Sel ($Agent_m$, t_j)'s largest negotiation agent to become consultant agent. According to Task-Number which was the number of tenders for each task:

If ① Task-Number = 0, no tender, renegotiate; Otherwise, if ② Task-Number = 1, choose this tender agent to become consultant agent; Otherwise ③, Task-Number >1, select the largest evaluation value of bidding Agent to complete the Task's as the final consultant agent by Eqs. 12 and 13.

If management agent has not received a consultation intend in the limited time, it could send messages again or end the negotiation (Fig. 1 with dotted lines).

Step 5 It is not until each mission does not cooperate with agent that the calculation ends.

4 Application and Experiment

This paper is against the background of Robocop robot soccer, where the entire team is a typical MAS that considers robots as agents. Cooperation exists between adjacent positions of the players in the soccer process, such as passing, cooperation, etc. Coach (management agent) considers the performance of the players in the past (mental coefficient) when deciding which player to participate in the specific game. Then management agent selects the first 11 players who are most likely to win this game to participate in the game by evaluating all players' parameters.

The following test via relatively using mental coefficient Network and non-mental coefficient choose negotiation cost and the cost of task solving for the player to explain the effect of the mental coefficient's consulting.

Initial data set, when player successfully complete the requirement function, set $I_{t_j}^m = 1,\ I_{t_j}^m(w) = 1$, otherwise, $I_{t_j}^m = 0,\ I_{t_j}^m(w) = 0$. Self-confidence change factor $e = 0.1,\ r = 0.1$, initial busy is 0, reliability according to usual training results decision. When player successfully goals or passes, $q(\text{Agent}_m,\ t_j) = 1,$ else, $q(\text{Agent}_m,\ t_j) = 0$. When player scores in the playing time, $t(\text{Agent}_m,\ t_j) = 1,$ else$t(\text{Agent}_m,\ t_j) = 0.K_q = 0.8,\ K_t = 0.2,\ K_w$ is a random number.

Assume that there are 20 players, coach (management agent) needs to choose 11 players to become formal players, the rest of the nine for bench players. The number of games is from 5 to 30. The Example of negotiation cost of football match are shown in Fig. 3, and the example of cost of task solving in football match are shown in Fig. 4.

The horizontal axis represents the number of games; the ordinate axis cost represents the negotiation cost in Fig. 3; the ordinate axis cost represents the cost of task solving in Fig. 4. We can see from the above test results that the negotiation cost of classic contract net consultative is far higher than contract net protocol based on mental coefficient. This is mainly due to classified each agent of mental contract net, and only sends a message to acquaintance and general acquaintance which improves the traditional way of broadcasting. However, it is basically flat about the cost of task solving. We can see from Fig. 4 that with the growth of task, the advantage of contract net is based on the mind, so mental coefficient contract net is more suitable for multi-agent.

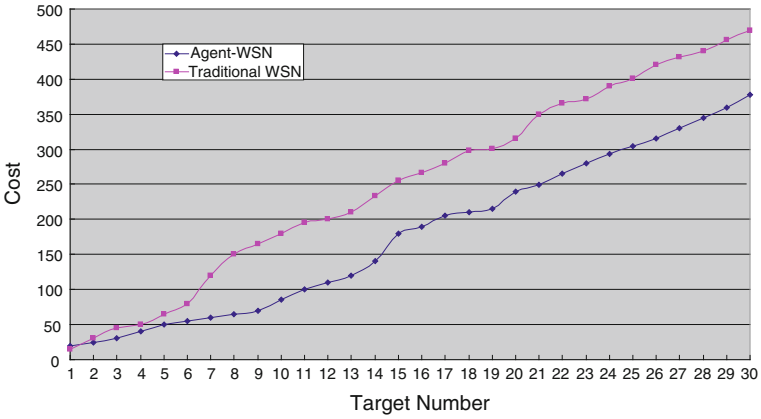

Fig. 3 Example of negotiation cost of football match

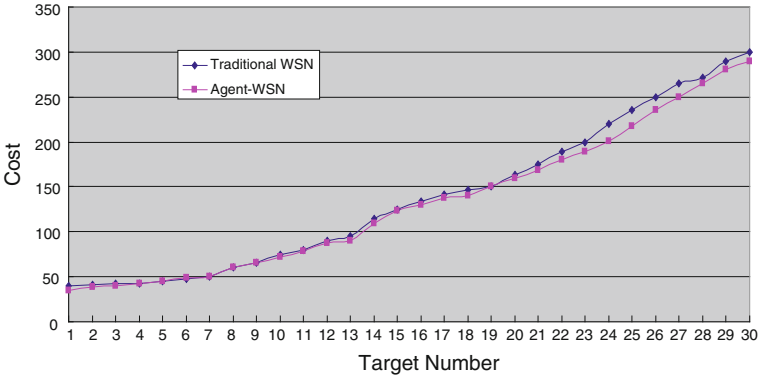

Fig. 4 Example of cost of task solving in football match

5 Conclusion

This paper aims at the large scale of MAS system, which pays the expense of the classic contract net which is large and its spread is slow. Having imported the acquaintance model and the mental coefficient into the classic contract net, it constructs a network based on the mental state contract negotiation model architecture. The confidence of mental state, familiarity, reliability, busy condition described agent's social attribute, and noted down the historical cooperation with the agents.

It has increased the efficiency of the negotiation based on the quality of negotiation. But it is simple being the update role of confidence between mental coefficients just according to the related proportion factor. So it is a possibility that the self-confidence and comprehensive evaluation are maybe generally alike,

which will lead to the weakness of the mental coefficients during the mission distributing. In the meantime, it will unexpectedly increase the cost of calculate, which is necessary to how to update every factor of mental coefficients in the subsequent research. This is an important subsequent research.

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References

1. Holm TS, Lesser VR (1997) Coalition among computationally bounded agents. Artif Intell 94:99–137
2. Holm TS, Lesser VR (1996) Advantages of a leveled commitment contracting protocol. In: Proceedings 13th national conference on artificial intelligence. AAAI Press, Menlo Park, CA, pp 126–133
3. Chen X-G (2004) Further extensions of FIPA contract net protocol: threshold plus doe. In: Proceedings of 2004 ACM symposium on applied computing. ACM Press, New York, pp 135–141
4. Fischer K, Muller JP (1995) A model for cooperative transportation scheduling. In: Proceedings of the 1st international conference on multi-agent systems. MIT Press, Cambridge, pp 169–175
5. Collins J, Dahl BY et al (1998) A market architecture for multi-agent contracting. In: Proceedings of 2nd international conference on autonomous agents. ACM Press, New York, pp 256–278
6. Jun LK, Ski CY, Kym LJ (2000) Time-bound negotiation framework for electronic commerce agents. Decis Support Syst 26(2):319–331
7. Corny SE, Kawabata, Lesser VR, Meyer RA (1991) Multistage negotiation for distributed satisfaction. IEEE Trans Syst Man Cinematic 21(6):1462–1465
8. Wei Z-W, Qu Y-P Yan J-Y (2007) An improved dynamic contract nets. Comput Eng Appl 43(36):208–210 (in Chinese with English abstract) Beijing
9. Lan S-H (2002) The research of multi-agent technology and its application. Ph.D. thesis, Nanjing University of science and technology, Nanjing (in Chinese with English abstract)
10. Lin L, Feng L (2010) A multi-agent cooperation model based on improved contract net protocol. Comput Technol Dev 20(3):71–75
11. Wen HU (2010) Multi-robot system and key technology research based on MAS. Xihua University, Sichuan
12. Wang L-C Chen S-F (2002) A multi-agent and multi-issue negotiation model. J Softw 13(8):1637–1643 (in Chinese)
13. Zhang X-L, Shi C-Y (2007) A dynamic formation algorithm of multi-agent coalition structure 18(3):574–581 (in Chinese with English abstract)
14. Tao H-J, Wang Y-D, Guo M-Z, Wang H-L (2006) A multi-agent negotiation model bases on acquaintance coalition and extended contract net protocol. J Comput Res Dev 43(7):1155–1160 (in Chinese with English abstract), ISSN, Beijing
15. Luo Y, Shi C-Y (1995) A behavior strategy of agent cooperation alliance. J Comput 40(6):961–965 (in Chinese)